Application of XP-SWMM
to the KISSIMMEE BASIN

XP SOFTWARE

Recent Relative XP Software Experience

- XP Software ported the UKISS model to Windows
- We also added graphics and refined some of the algorithms
- Recently integrated a 2-D model with XP-SWMM for overland flows
- New framework permits further development to distributed catchment modeling

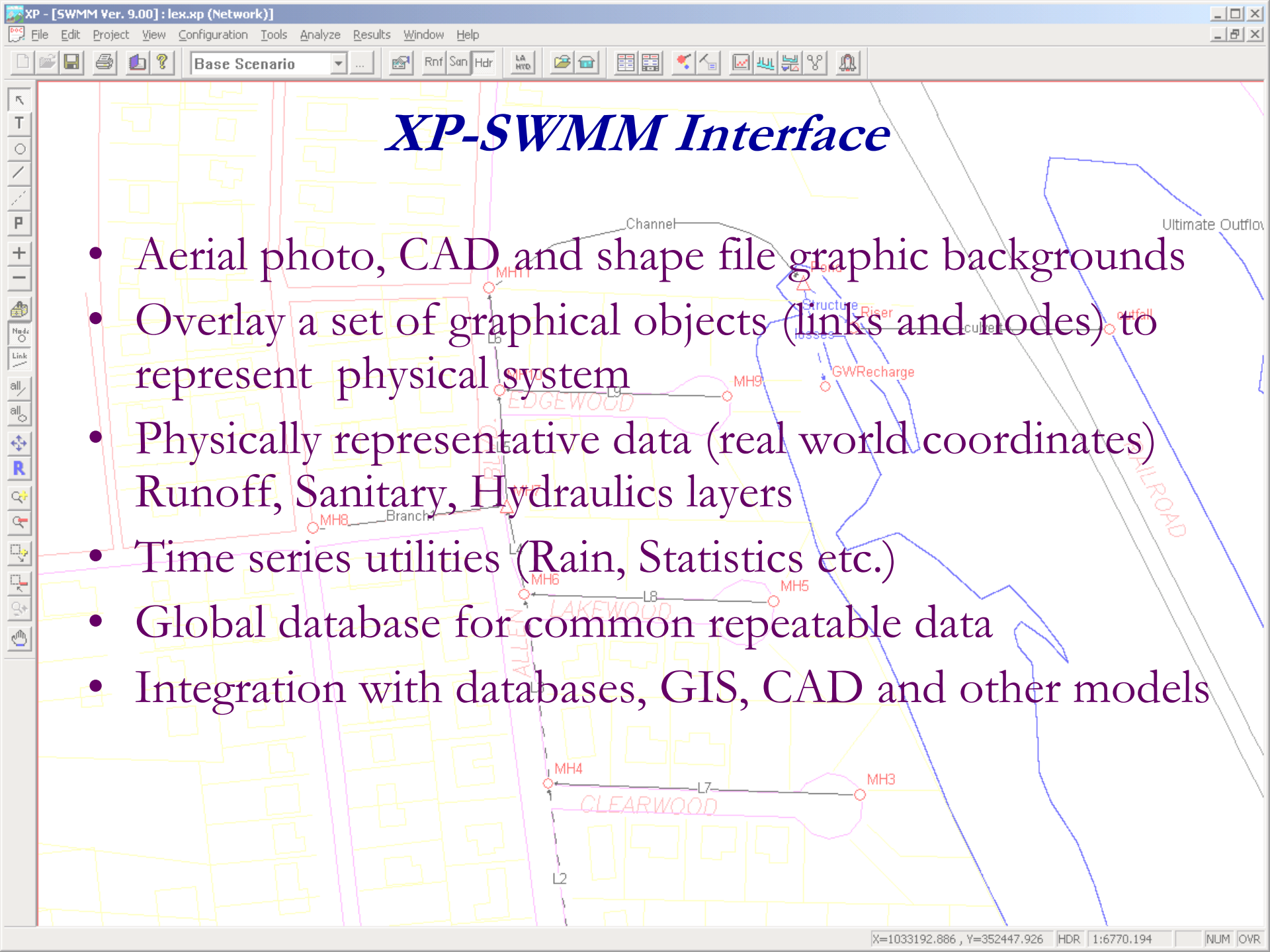
Description of XP-SWMM

- Modeling software for watershed, river, storm and wastewater management
- Decision support system encompassing a graphical user interface and an analytical engine
- The XP interface stands for the embedded eXPert system
- Analytical engine is based on EPA SWMM and contains numerous proprietary enhancements

XP SOFTWARE

XP-SWMM Interface

- Aerial photo, CAD and shape file graphic backgrounds
- Overlay a set of graphical objects (links and nodes) to represent physical system
- Physically representative data (real world coordinates) Runoff, Sanitary, Hydraulics layers
- Time series utilities (Rain, Statistics etc.)
- Global database for common repeatable data
- Integration with databases, GIS, CAD and other models



Basin Hydrology

- Surface hydrograph generation using 12 methods: RUNOFF, SCS, SBUH, Kinematic wave and many other unit hydrograph methods
- RUNOFF method is a deterministic model which can simulate: rainfall, snowmelt, infiltration, evaporation, and groundwater interaction
- Continuous and event simulations
- Simulate spatial and temporal variation in rainfall
- Catchment parameters: lumped (subcatchment basis)
- Redirect surface flows – Low Impact Development
- Water quality (generate non point source pollutographs)
- Global Storms –(simulate multiple return periods)
- BMP in hydrology layer

XP SOFTWARE

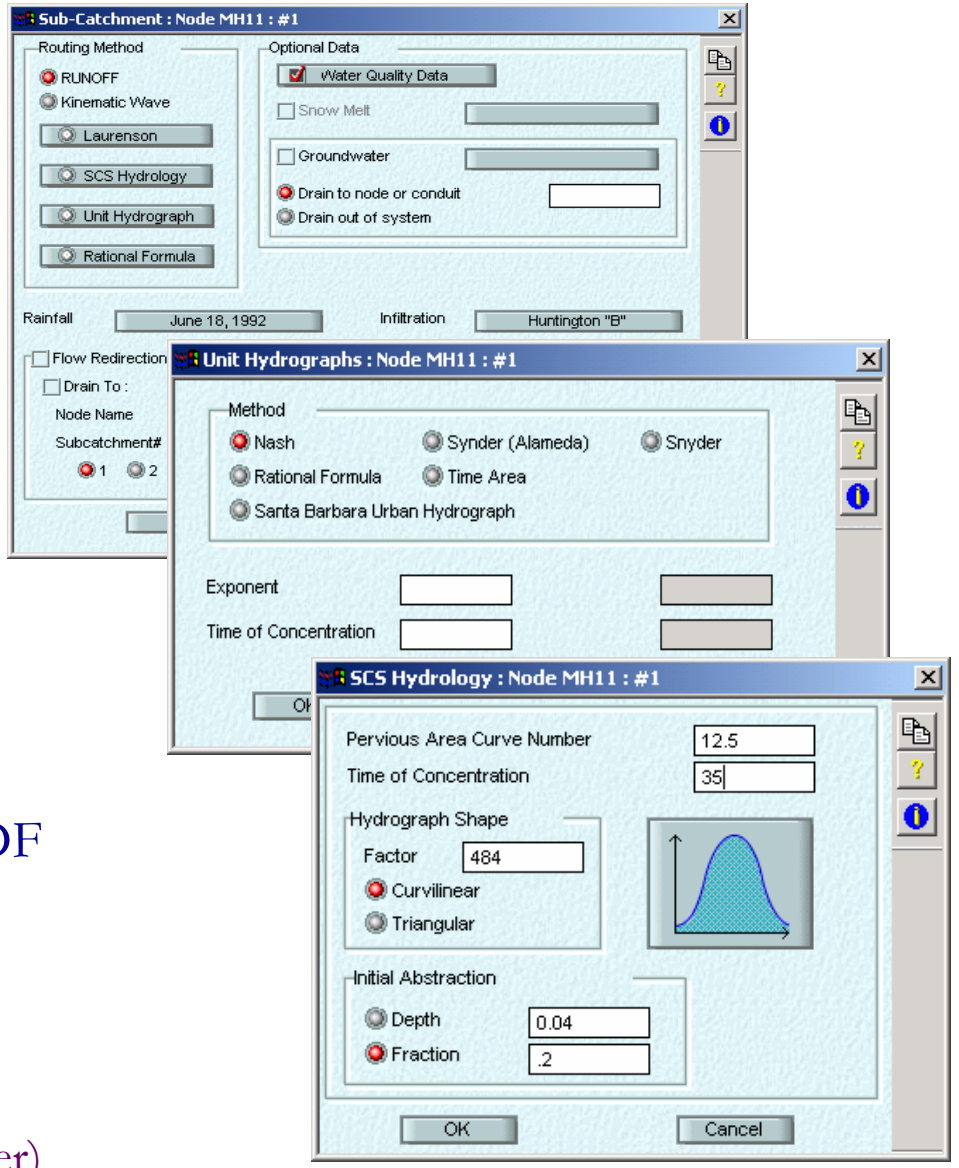
Basin Hydrology – Losses

- Initial abstractions are simulated by unique depression storage depths for impervious and pervious surfaces on each subcatchment
- Infiltration by Horton, Green-Ampt and initial, proportional and continuing loss methods
- Continuous simulations infiltration capacity and surface storage is recovered
- Horton infiltration allows cumulative infiltration volume cutoff to limited soil storage
- Infiltration is optionally coupled to the groundwater
- Evaporation as daily or monthly averages
- Evaporation as a continuous time series

XP SOFTWARE

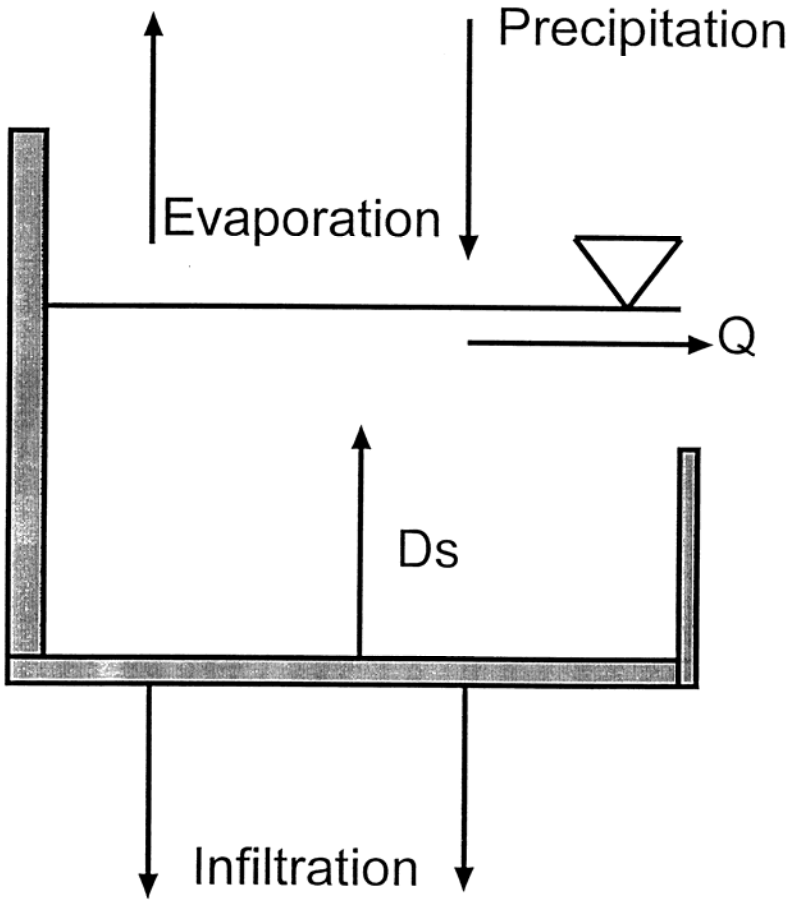
Hydrology Methods

- 12 different methods
  - SWMM RUNOFF
  - Kinematic Wave
  - Laurenson
  - SCS
  - Unit Hydrographs
    - SBUH
    - Snyder
    - Rational Formula
    - Time Area
    - Nash
  - Rational Method Uses IDF
  - Plus Regional Methods
    - LA County Method (MORA)
    - CUHP
    - Alameda County (Snyder)



XP SOFTWARE

RUNOFF Layer Conceptualization

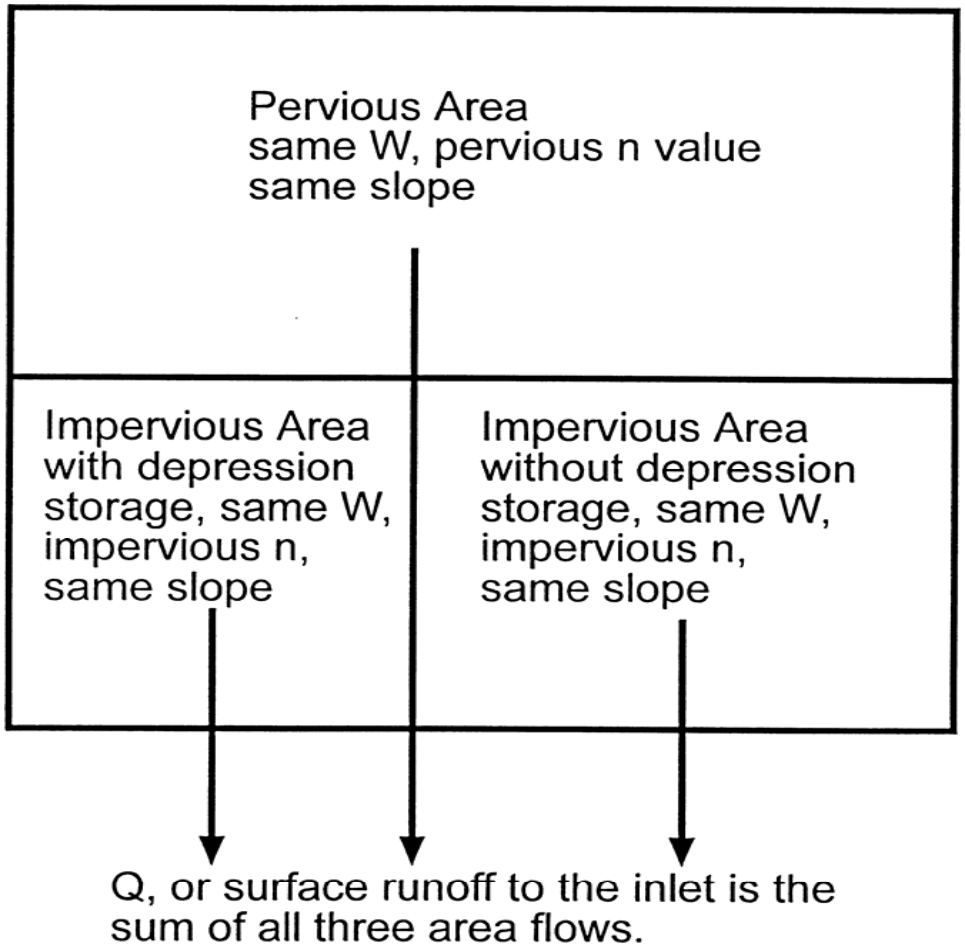


$$Q = \frac{1.486}{n} \bullet W \bullet (d - d_s)^{5/3} \bullet S^{1/2}$$

EPA Surface Runoff
Non-linear Reservoir

XP SOFTWARE

Catchment Surfaces

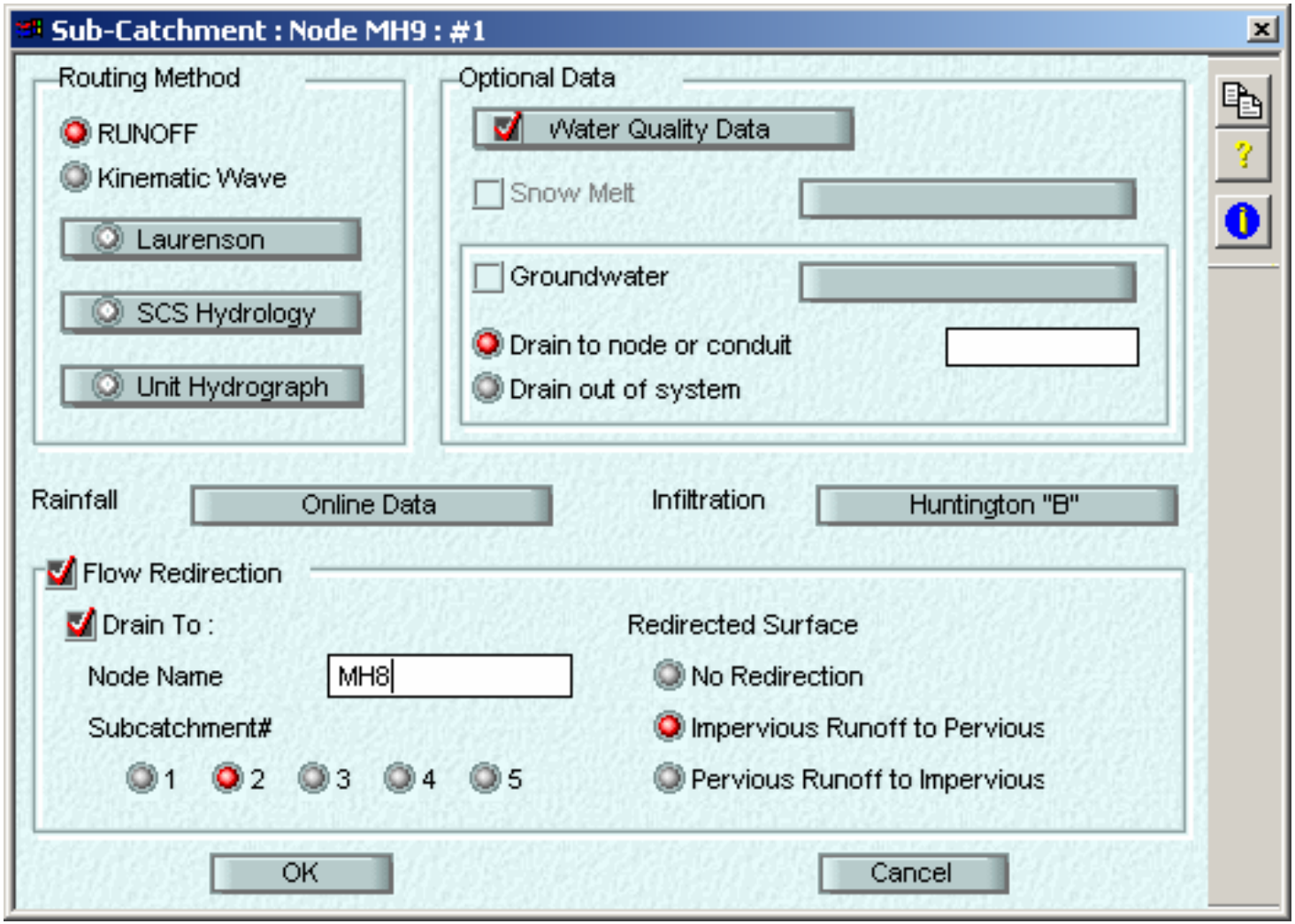


Note: Impervious and pervious areas have a different W/n ratio for calibration.

XP SOFTWARE

Surface Flow Redirection

- Redirect flows by surface and between subcatchments
- Permits LID and source control BMP modeling



XP SOFTWARE

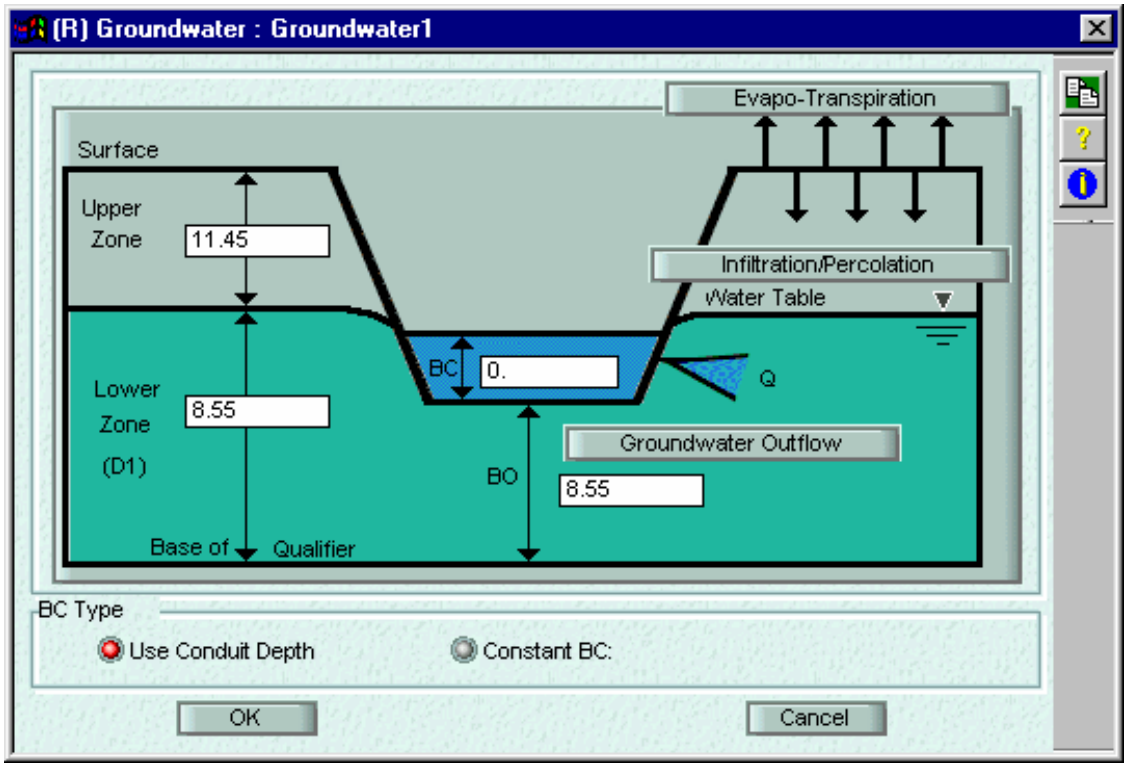
Infiltration Procedures

- Horton
- Horton with cumulative maximum infiltration
- Green-Ampt
- Initial and continuing loss
- Initial and proportional loss
- All the above optionally connected to groundwater
- Losses associated with the unit hydrograph method:
  - SCS - loss rates & fraction initial abstraction
  - SCS - loss rates & fixed depth initial abstraction

XP SOFTWARE

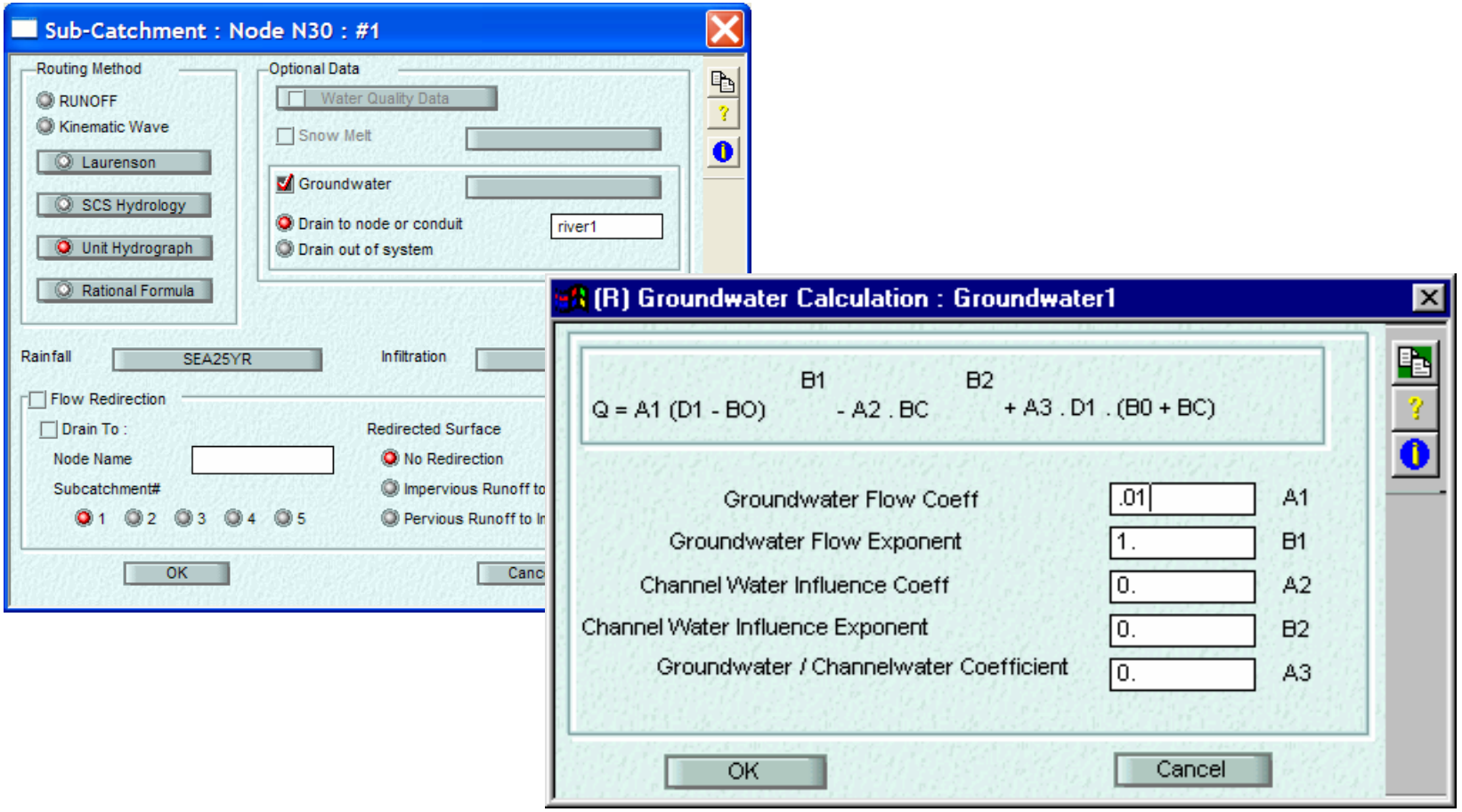
Basin Hydrology - Groundwater

- Subsurface hydrology using 2 compartment groundwater module
- Each subcatchment has its own groundwater storage
- High groundwater table can cut off infiltration
- Groundwater between subcatchments not currently simulated



Groundwater Flows

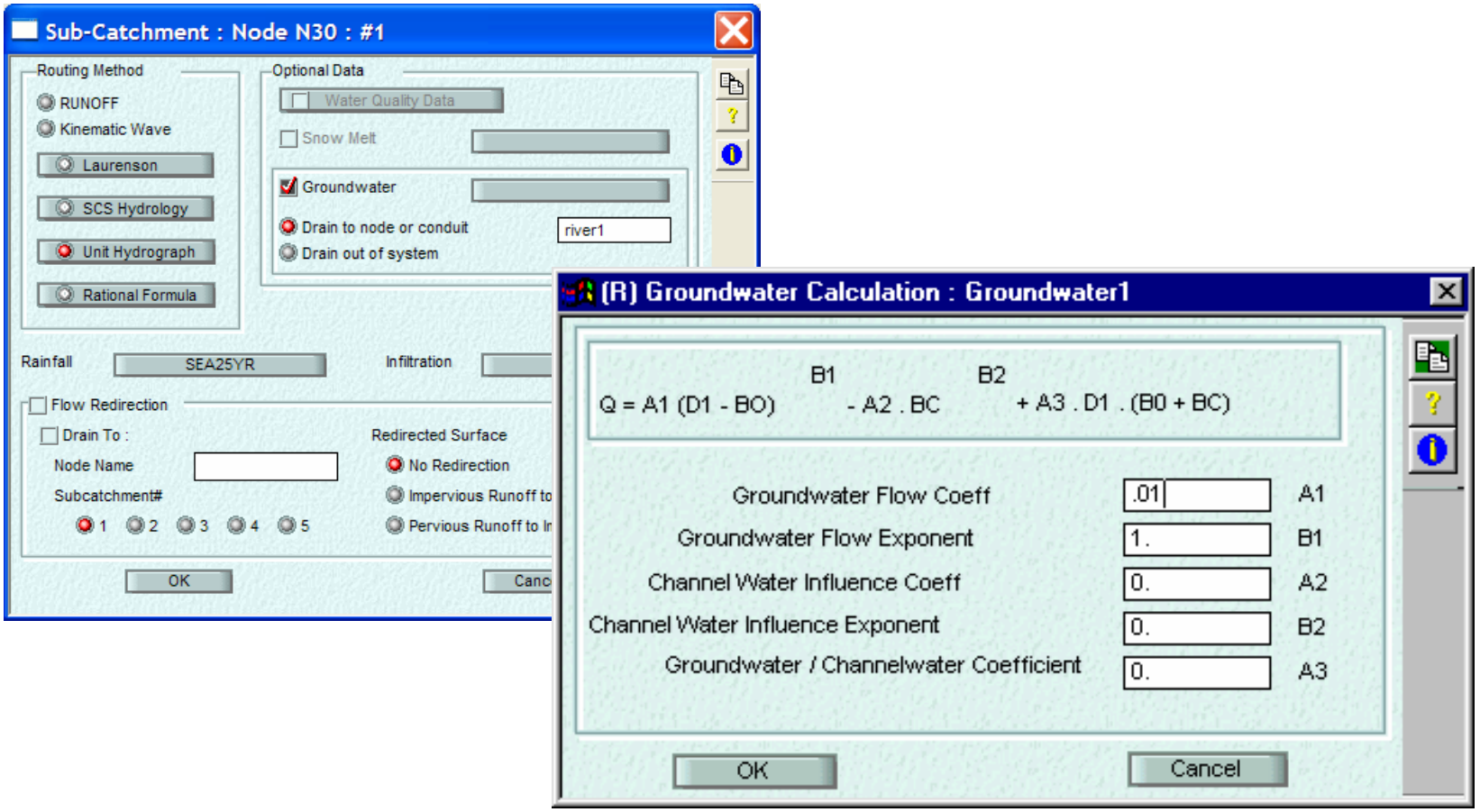
- Groundwater flow can be redirected to other nodes or links
- Groundwater flow can be drained out of the system
- Boundary condition can be static or dynamic conduit depth



XP SOFTWARE

Groundwater Hydraulics

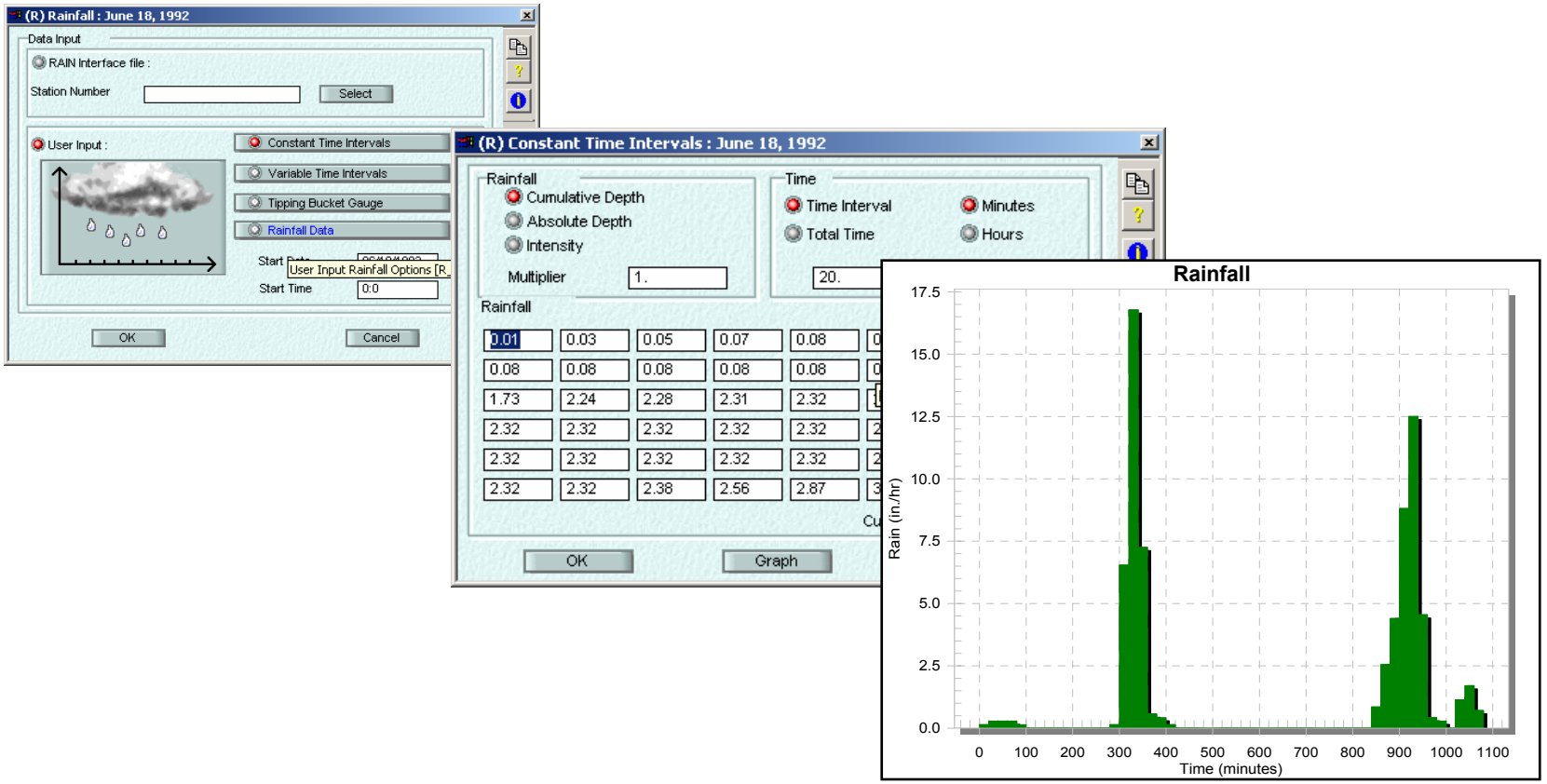
- No current groundwater interaction between subcatchments
- With software developments:
  - This could be easily simulated with a rating curve
  - XP-SWMM could be integrated with MODFLOW



XP SOFTWARE

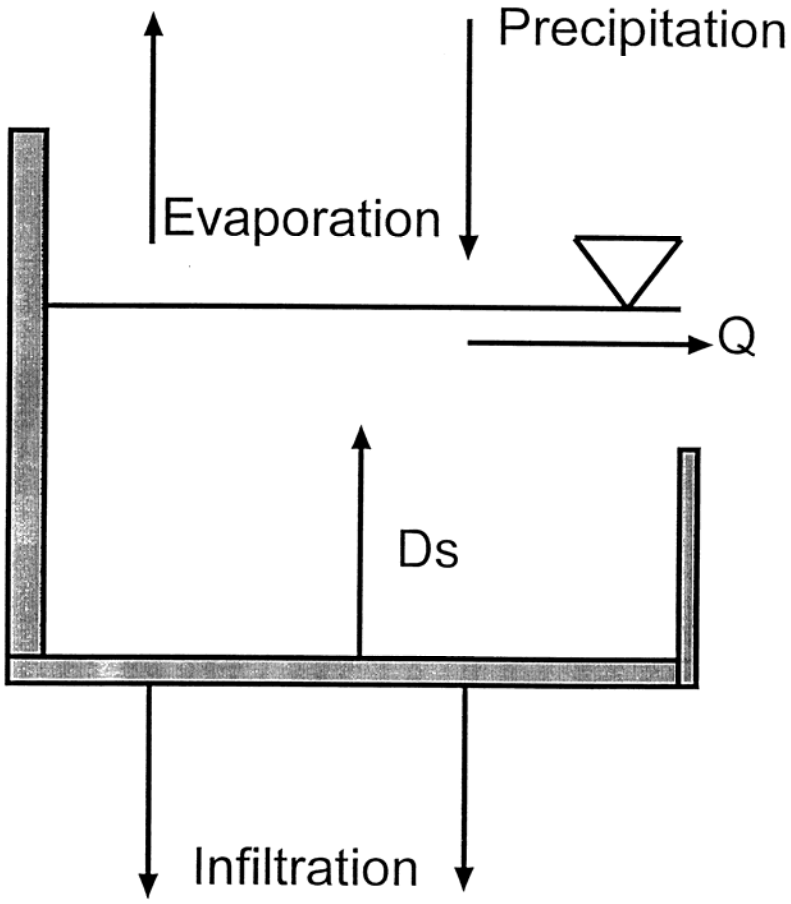
Flexible Rainfall Data Input

- Single event or continuous rainfall stored in or linked to XP
- Constant or variable time steps
- Design storms i.e. 72-hr SWFWMD
- Generate statistics on rain and graph the storms
- Import and analyze NWS, Earth Info, and user defined rainfall



XP SOFTWARE

Catchment Conceptualization

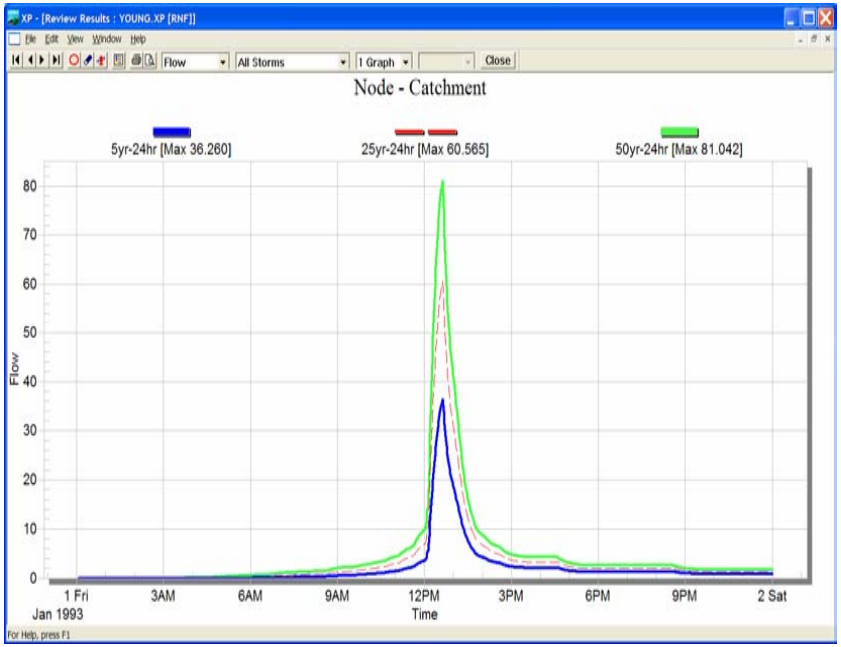


$$Q = \frac{1.486}{n} \bullet W \bullet (d - d_s)^{5/3} \bullet S^{1/2}$$

EPA Surface Runoff
Non-linear Reservoir

XP SOFTWARE

Global Storms



XP - [SWMM Ver. 9.50] : YOUNG.XP:2 (Table)]

File Edit View Options Format Window Help

Name	Storm	Max Water Elevation (ft, m)	Max Surface Area (ft^2, m^2)	Node Inflow (ft^3, m^3)
Catchment	5yr-24hr	15.000	12.57	180929.368
	25yr-24hr	15.000	12.57	309130.857
	50yr-24hr	15.000	12.57	420159.910
Pond A1	5yr-24hr	9.976	86589.44	0.000
	25yr-24hr	10.132	90949.91	0.000
	50yr-24hr	10.215	93374.81	0.000
mh a1	5yr-24hr	5.066	12.57	0.000
	25yr-24hr	5.167	12.57	0.000
	50yr-24hr	5.234	12.57	0.000
Tide Outf.	5yr-24hr	3.044	12.57	0.000
	25yr-24hr	3.160	12.57	0.000
	50yr-24hr	3.232	12.57	0.000

Pond Stage

OVR

Global Storms

	Name	Return Period	Rainfall	Overide Multiplier	Multiplier
☑	5yr-24hr	5	SCS Type II	☑	5.2
☑	25yr-24hr	25	SCS Type II	☑	7.8
☑	50yr-24hr	100	SCS Type II	☐	10.00

OK

Cancel

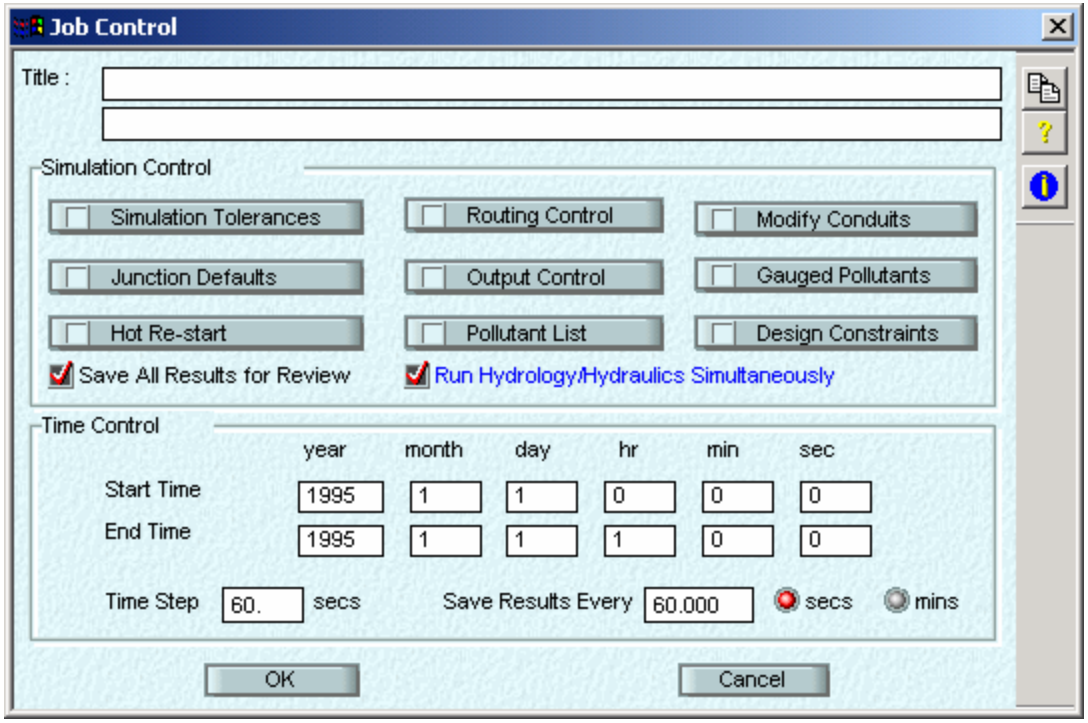
Insert Storm

Delete Storm

XP SOFTWARE

Combined Hydrology and Hydraulics

- "Simultaneous" option allows Hydraulics to run at the same time as Runoff without the need for interface files.



- Dynamic depths of the conduits in Hydraulics can be linked to the Runoff groundwater module.

XP SOFTWARE

Hydraulics (Extran) Layer

- Dynamic wave routing (St. Venant equations)
- Fast solution with variable time step
- Handles multiple boundary conditions
- Simulates networks of open and closed conduits
- Handles multiple conduits, pumps, weirs, orifices
- Handles looped networks & adverse sloped conduits
- Can also route water quality
- Has several Real Time Control elements & capabilities
- Superior solution (more stable & capable than EPA)
- Inlet capacity analysis for dual drainage
- Real Time Control module (add-on)

XP SOFTWARE

St. Venant Equations

Continuity Equation: (Conserves Mass)

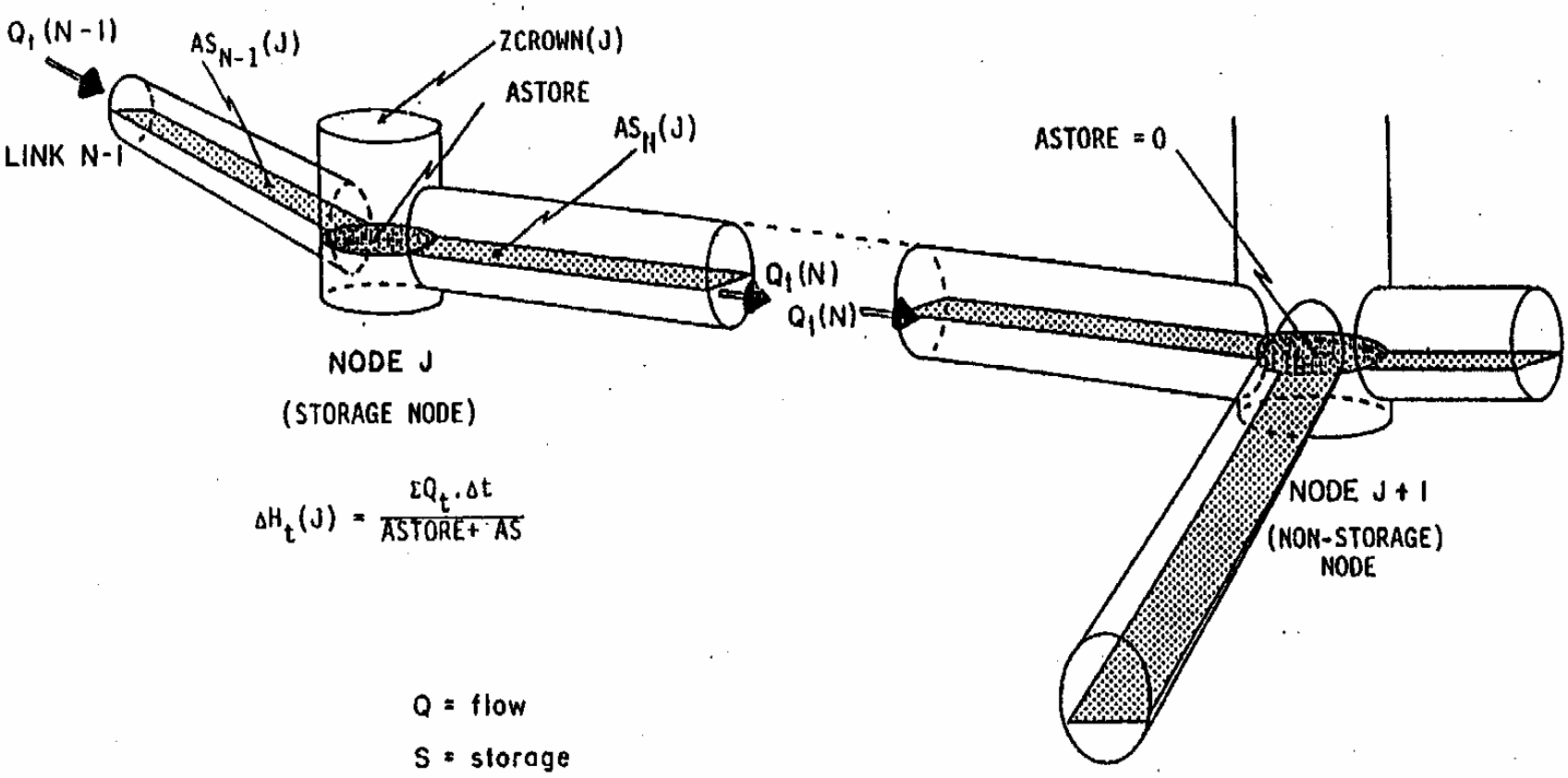
$$\frac{\partial A}{\partial t}+\frac{\partial Q}{\partial x}=0$$

Momentum Equation:(Conserves Energy)

$$\frac{\partial Q}{\partial t}+\frac{\partial\left(\frac{Q^2}{A}\right)}{\partial x}+gA\frac{\partial y}{\partial x}+gA\left(S_e+S_c+S_f-S_o\right)=0$$

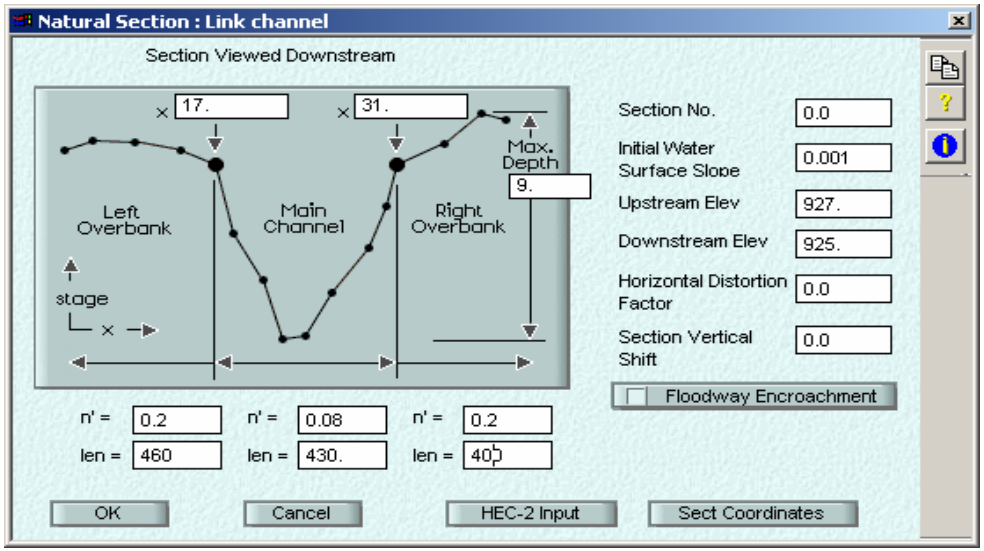
XP SOFTWARE

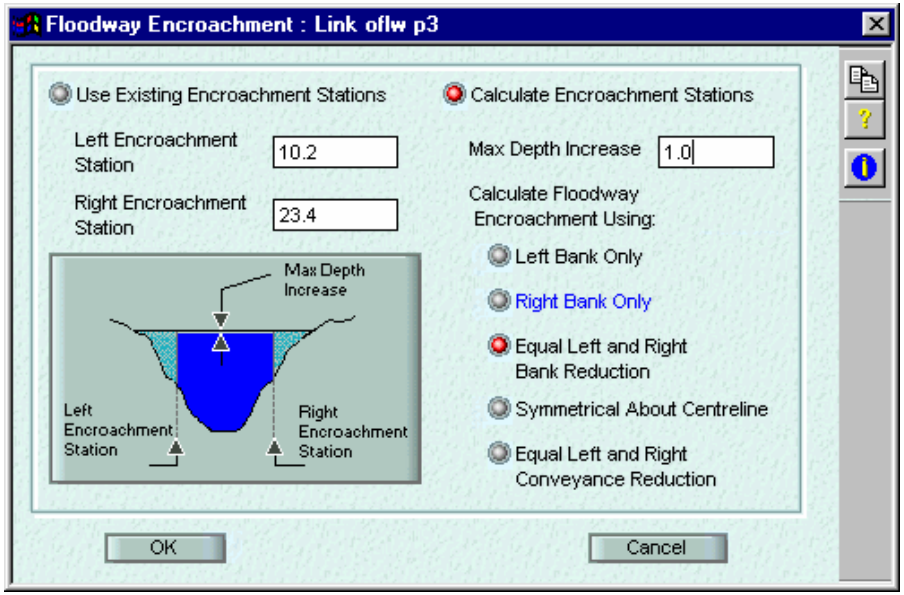
Link Node Representation



XP SOFTWARE

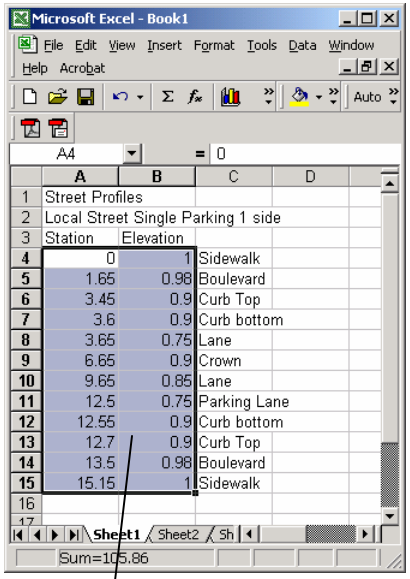
Natural Channel Definition



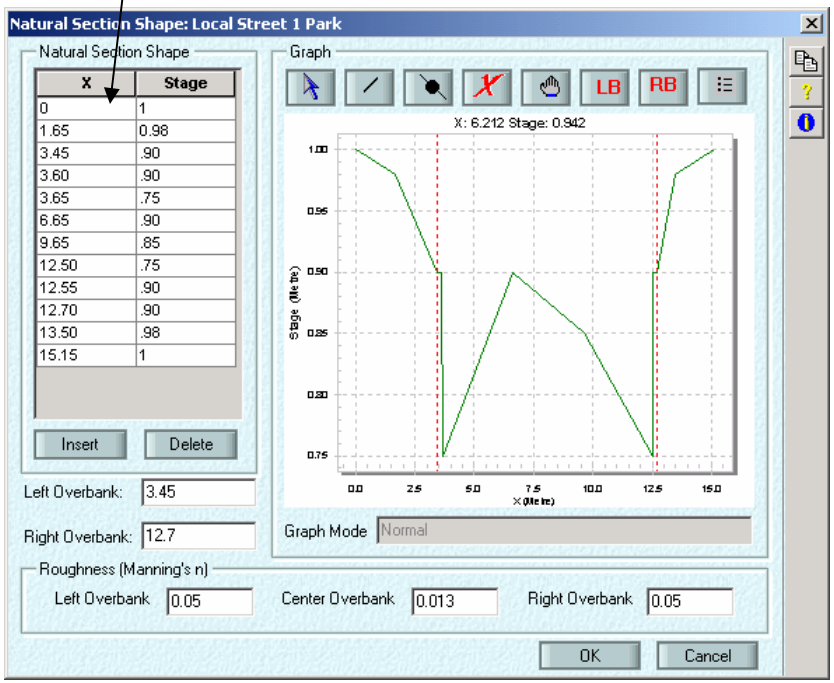


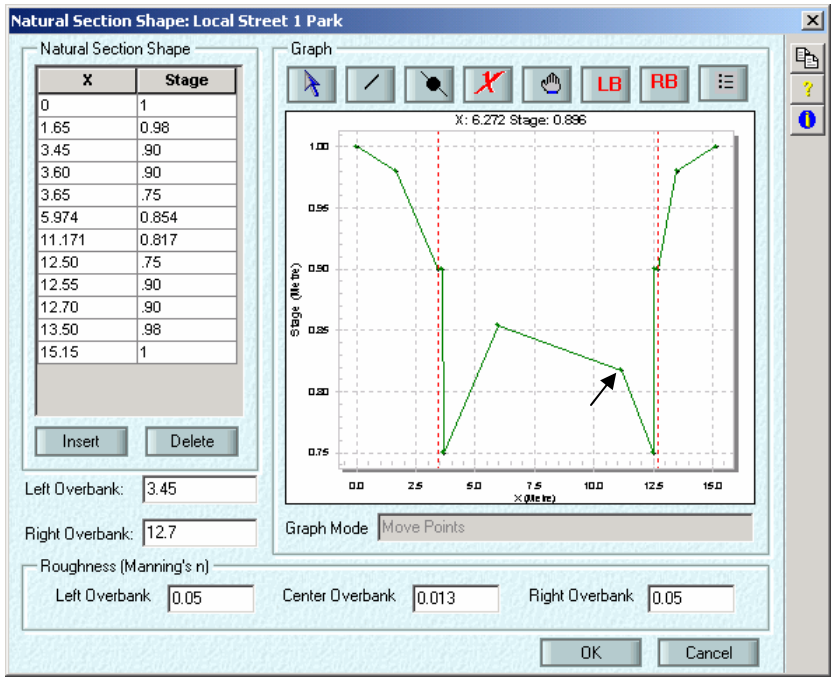
XP SOFTWARE

Natural Channel: Editing



- Copy and paste cross-section geometry
- Tabular or graphic editing of channel geometry as shown below by clicking and dragging the points
- Graphically select left and right overbank stations
- Store sections in the Global Database

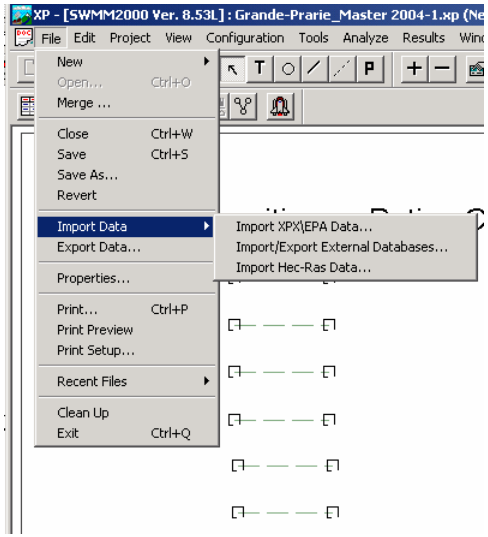


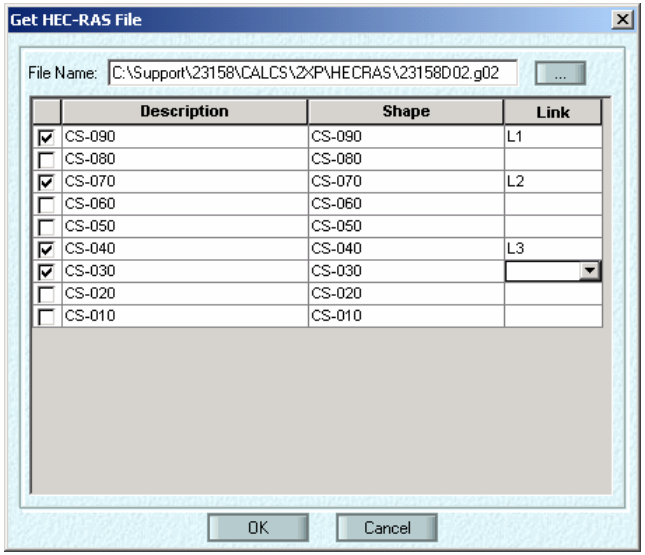


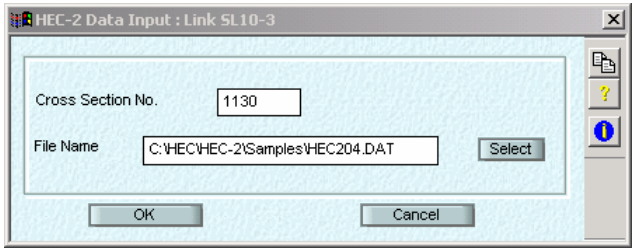
XP SOFTWARE

Natural Channel Import and Storage

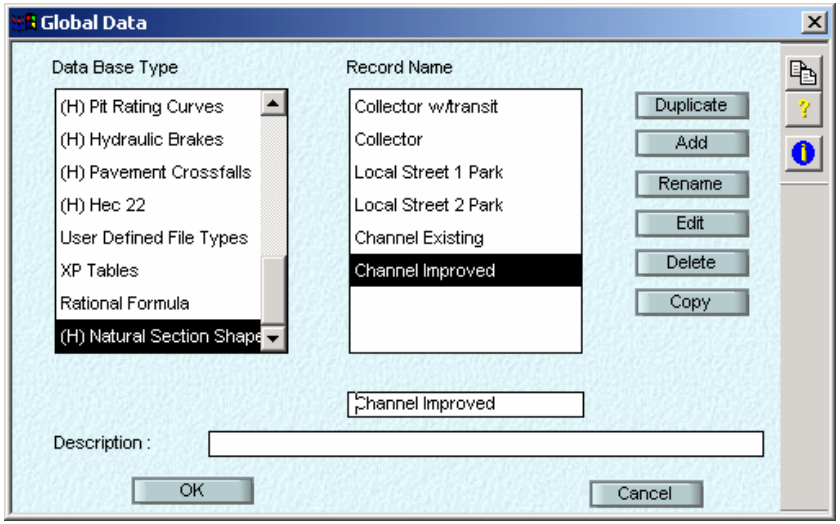
- Import natural channel geometry from HECRAS or HEC-2







- Store and merge natural channel geometry in the global database



XP SOFTWARE

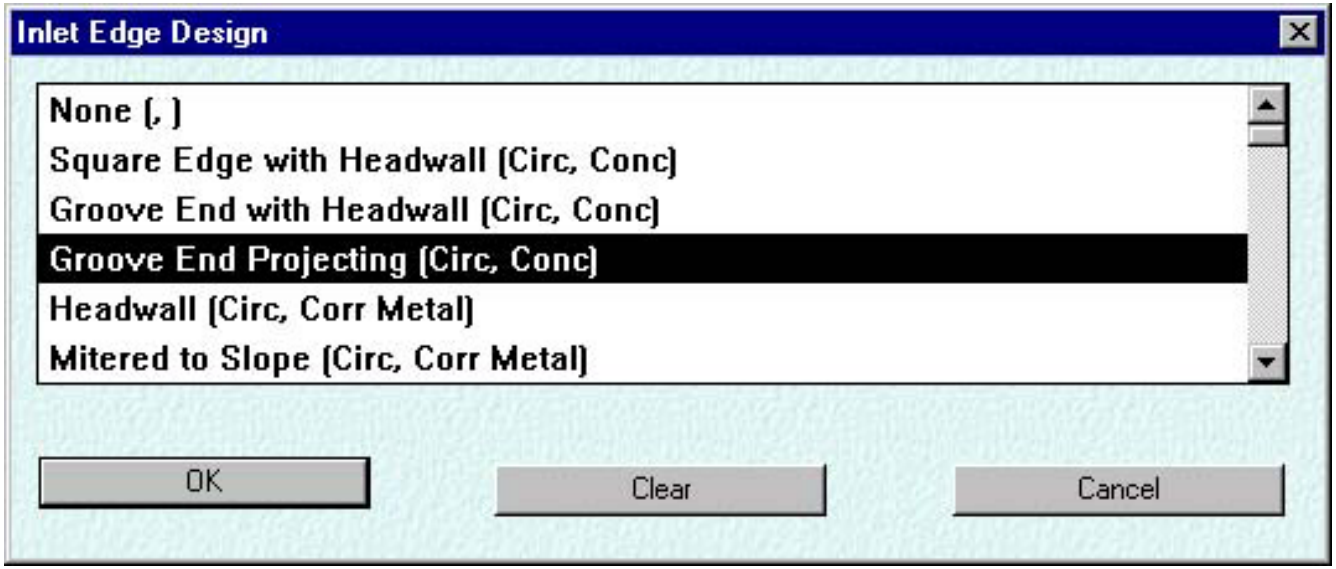
Hydraulic Elements and Structures

- Open and closed conduits including surcharged closed conduits
- Junctions, manholes, inlets, catchbasins and outfalls
- Inline and offline storage nodes i.e. lakes, ponds, wetlands and wide channels
- Side and bottom outlet circular and rectangular orifices
- Transverse and side flow weirs
- User defined weirs
- Pumps Rated by: dynamic head, depth or wet well volume
- Rating curves and flows specified by defined user equations
- Regulators, inflatable and bendable weirs
- Flexible BMP as storage and screening devices
- RTC of the above structures

XP SOFTWARE

FHWA Inlet Control Equations for Culverts

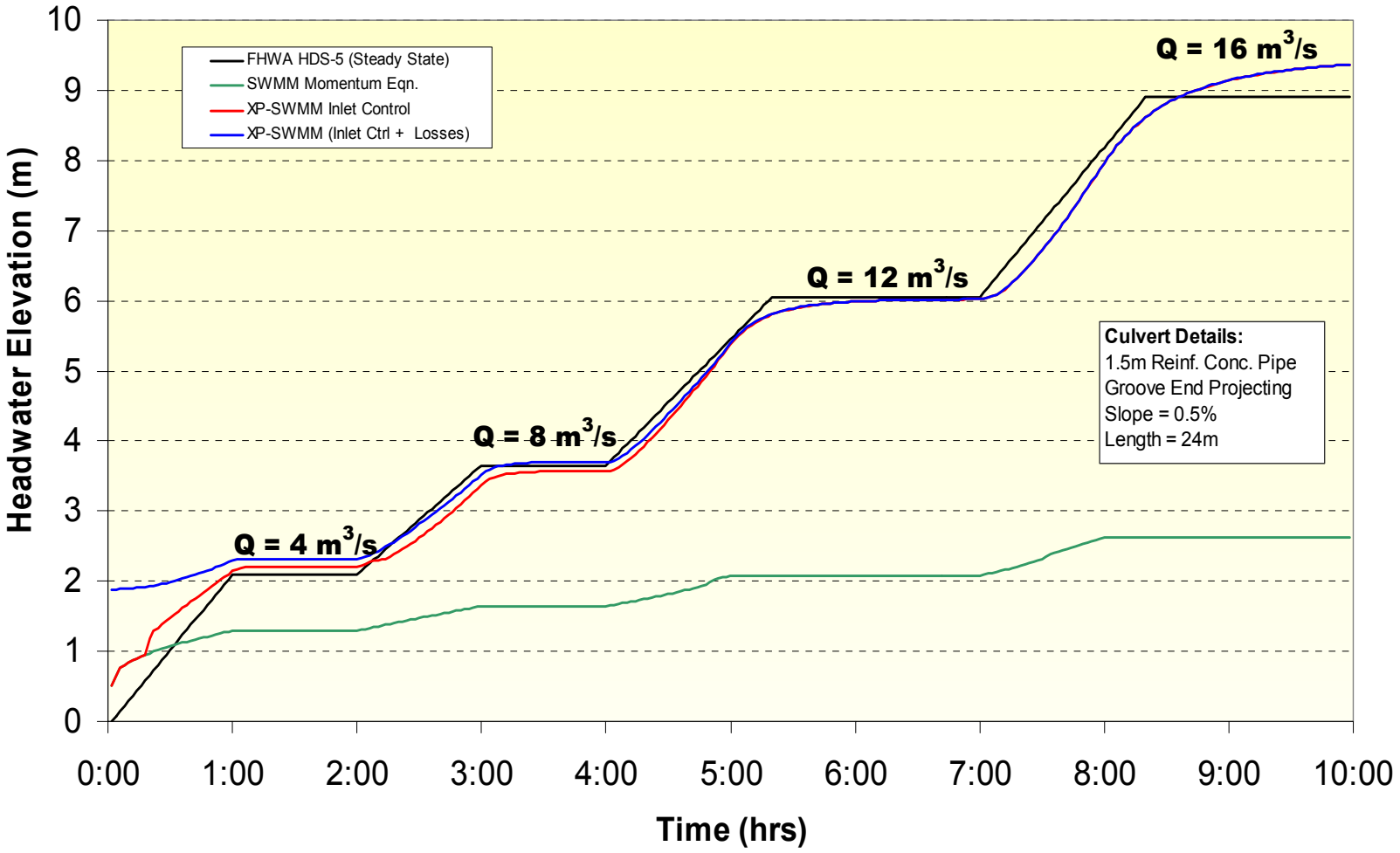
- The head under inlet control may be significantly greater than that estimated assuming outlet control.
- XP-SWMM uses Inlet Control equations from the FHWA's "Hydraulic Design of Highway Culverts".
- Select from 58 inlet configurations



XP SOFTWARE

Inlet Control

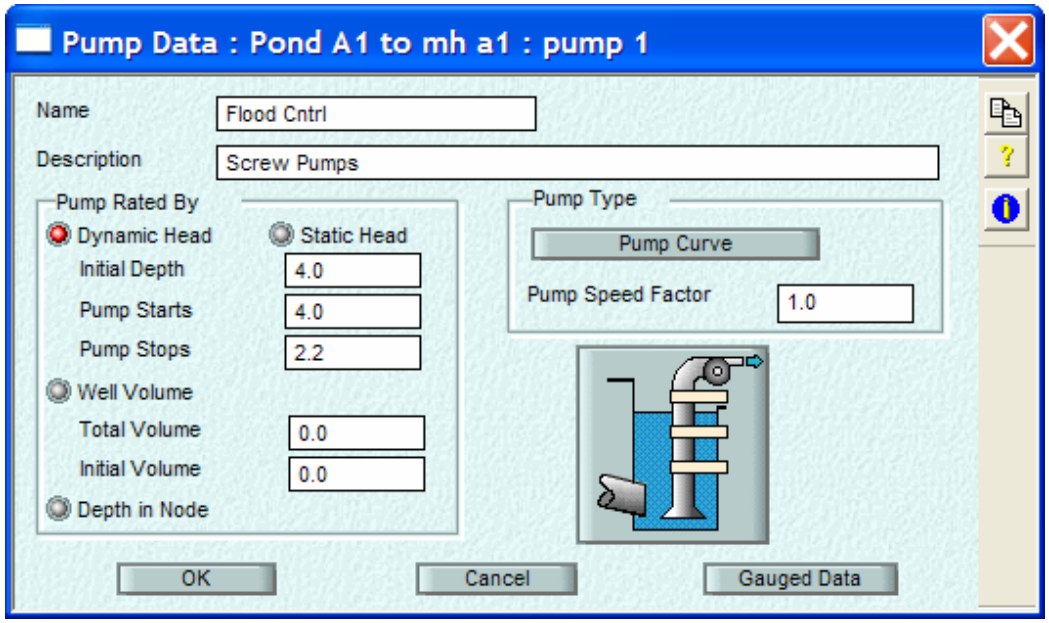
Comparison of Culvert Headwater Elevation for Various Flow Control Conditions and Flow Rates



XP SOFTWARE

Pump Options

- Pump curves are stored in the Global Database
- Up to 7 pumps in a pump station
- Simulate variable speed pumps
- Generate flows based on pumping SCADA history



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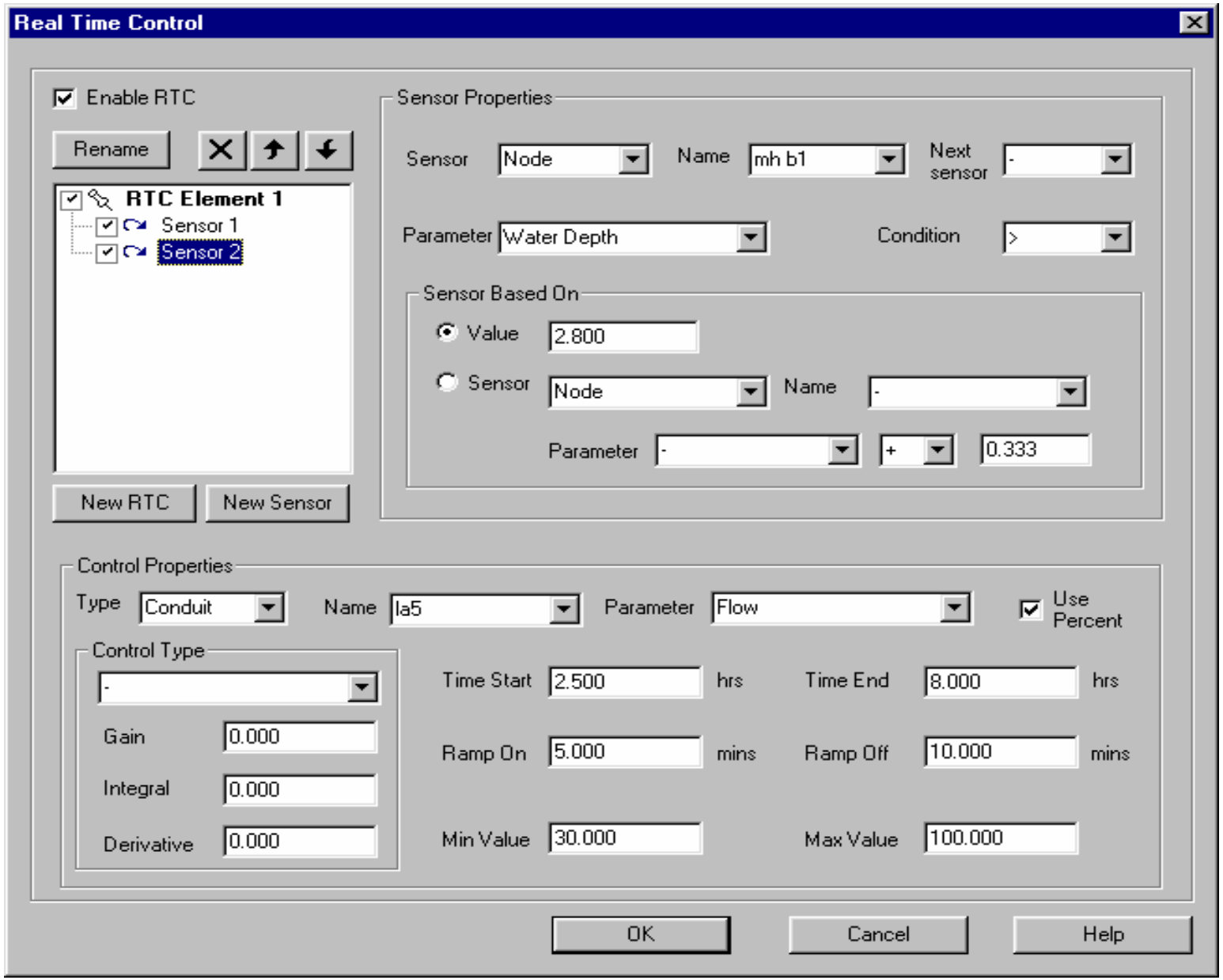
Real Time Control Module



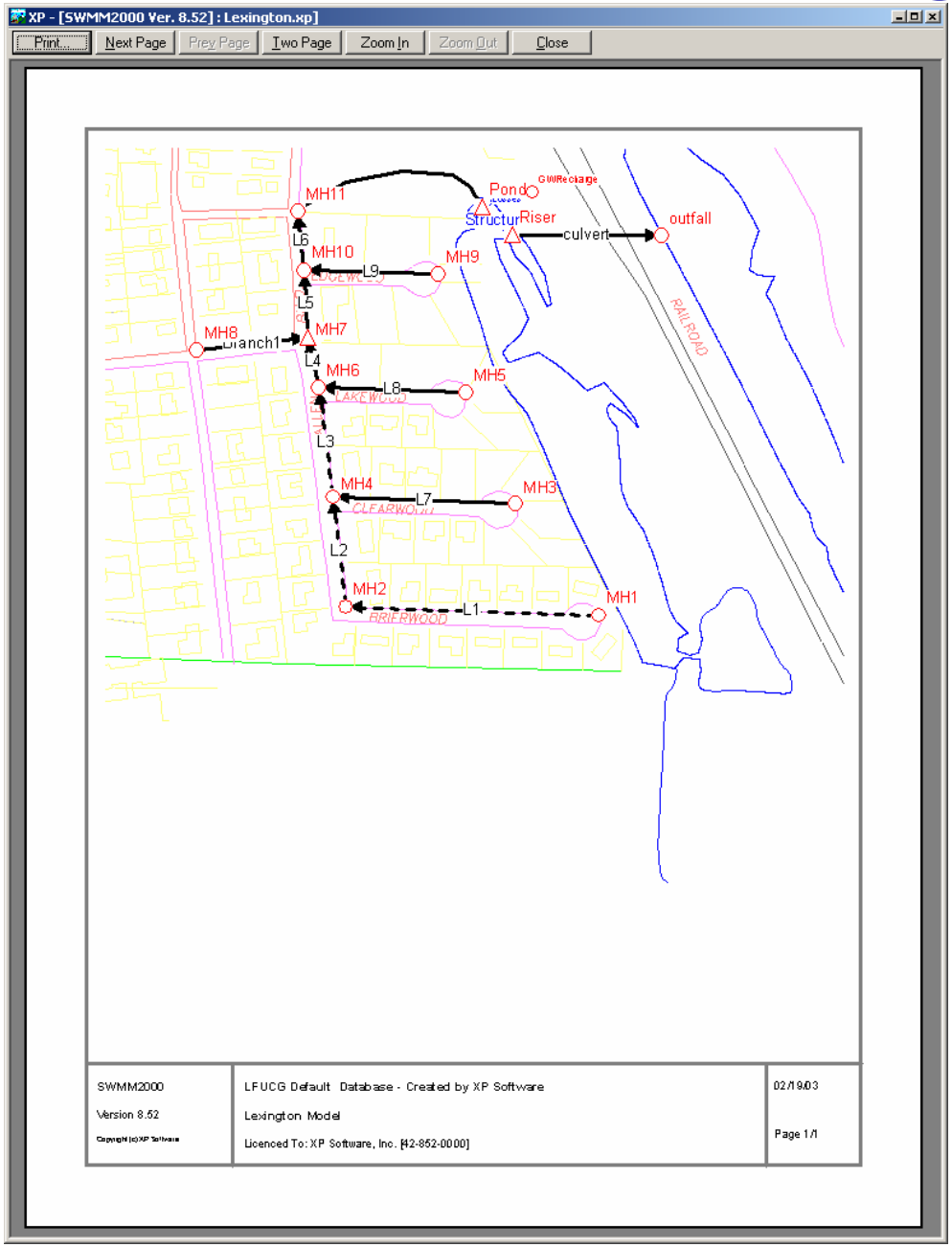
XP SOFTWARE

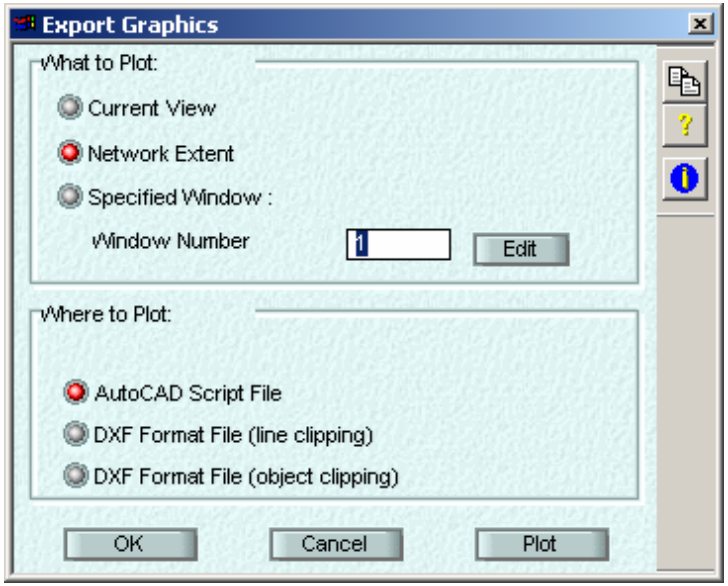
"Public Friendly" DSS Tools

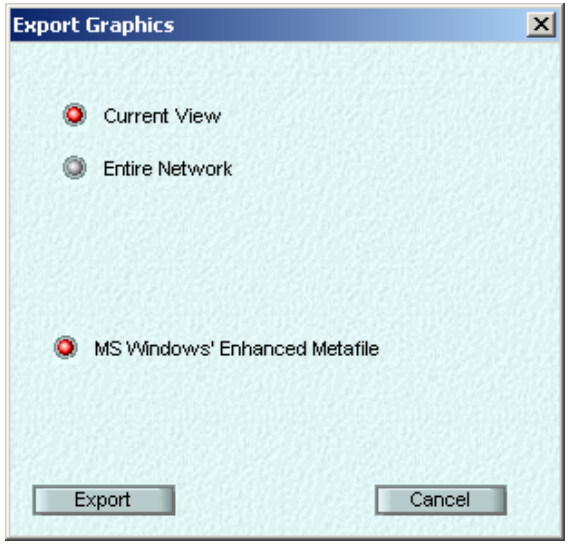
- Plan View Plotting and Plan View Export
- Comprehensive and Indexed Output File
- Review Results (Graphing of Time Series)
- Profile Plotting with Envelope of Maximums
- Dynamic Long Section View (Animation of HGL)
- Dynamic Section Views
- Dynamic Plan View
- Spatial Reports for Plan View Notation
- Graphical Encoding for Plan View Query
- Tabular Report (user-defined)
- XPX, RES and CSV Output to GIS or Databases
- XP Tables and Quick Data View Forms
- Interactive Analysis Engine & Run Time Graphing

XP SOFTWARE

Plan View Plotting and Export







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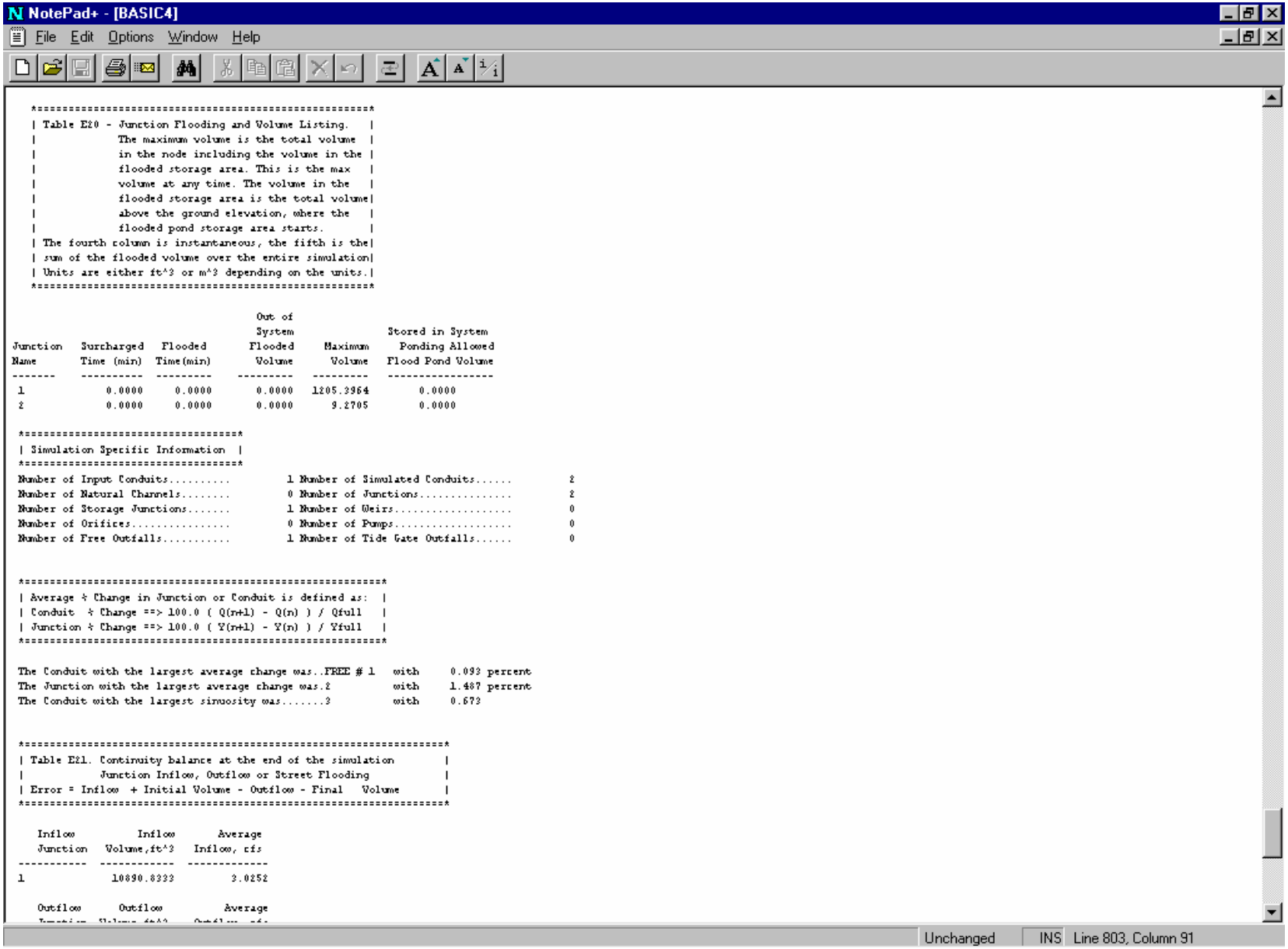
Output File



NotePad+ - [BASIC4]

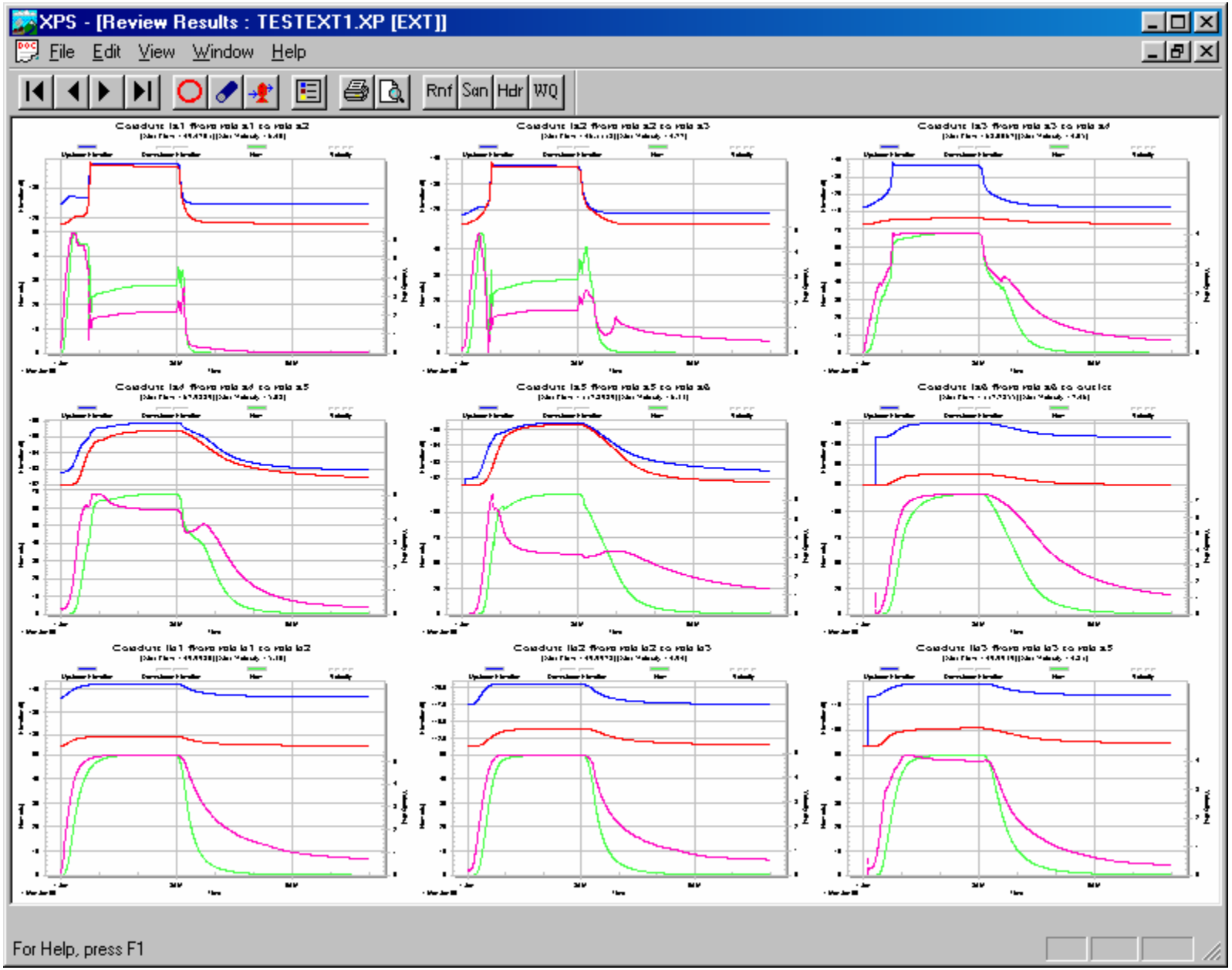
File Edit Options Window Help

```
  *******************************************************
  | Table E20 - Junction Flooding and Volume Listing.   |
  |             The maximum volume is the total volume  |
  |             in the node including the volume in the |
  |             flooded storage area. This is the max   |
  |             volume at any time. The volume in the   |
  |             flooded storage area is the total volume|
  |             above the ground elevation, where the   |
  |             flooded pond storage area starts.       |
  | The fourth column is instantaneous, the fifth is the|
  | sum of the flooded volume over the entire simulation|
  | Units are either ft^3 or m^3 depending on the units.|
  *******************************************************

                                    Out of
                                    System                Stored in System
Junction   Surcharged   Flooded     Flooded     Maximum     Ponding Allowed
Name       Time (min)   Time(min)    Volume      Volume   Flood Pond Volume
-------    ----------   ---------  ---------   ---------  -----------------
1             0.0000      0.0000     0.0000   1205.3964        0.0000
2             0.0000      0.0000     0.0000      9.2705        0.0000

 ***********************************
 | Simulation Specific Information  |
 ***********************************
 Number of Input Conduits.....          1 Number of Simulated Conduits.....          2
 Number of Natural Channels.....        0 Number of Junctions.....                   2
 Number of Storage Junctions.....       1 Number of Weirs.....                       0
 Number of Orifices.....                0 Number of Pumps.....                       0
 Number of Free Outfalls.....           1 Number of Tide Gate Outfalls.....          0


 ***********************************************************
 | Average % Change in Junction or Conduit is defined as:  |
 | Conduit  % Change ==> 100.0 ( Q(n+1) - Q(n) ) / Qfull   |
 | Junction % Change ==> 100.0 ( Y(n+1) - Y(n) ) / Yfull   |
 ***********************************************************

 The Conduit with the largest average change was..FREE # 1   with     0.092 percent
 The Junction with the largest average change was.2          with     1.487 percent
 The Conduit with the largest sinuosity was.......3          with     0.573


 *********************************************************************
 | Table E21. Continuity balance at the end of the simulation        |
 |            Junction Inflow, Outflow or Street Flooding            |
 | Error = Inflow  + Initial Volume - Outflow - Final   Volume       |
 *********************************************************************

    Inflow          Inflow       Average
    Junction   Volume,ft^3   Inflow, cfs
-----------   ------------  -------------
1              10890.8333         3.0252

    Outflow       Outflow          Average
```

Unchanged | INS | Line 803, Column 91

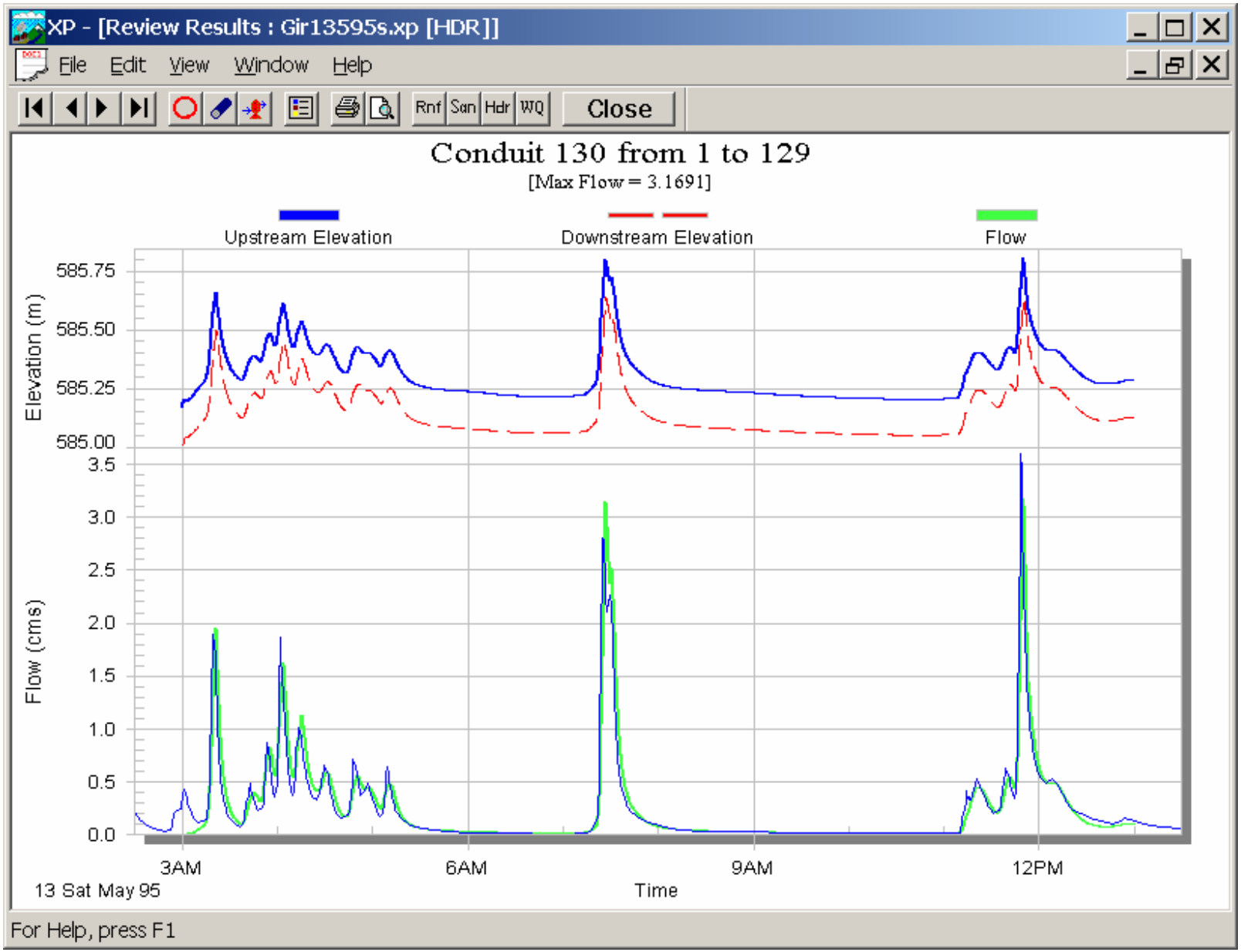
XP SOFTWARE

Review Results



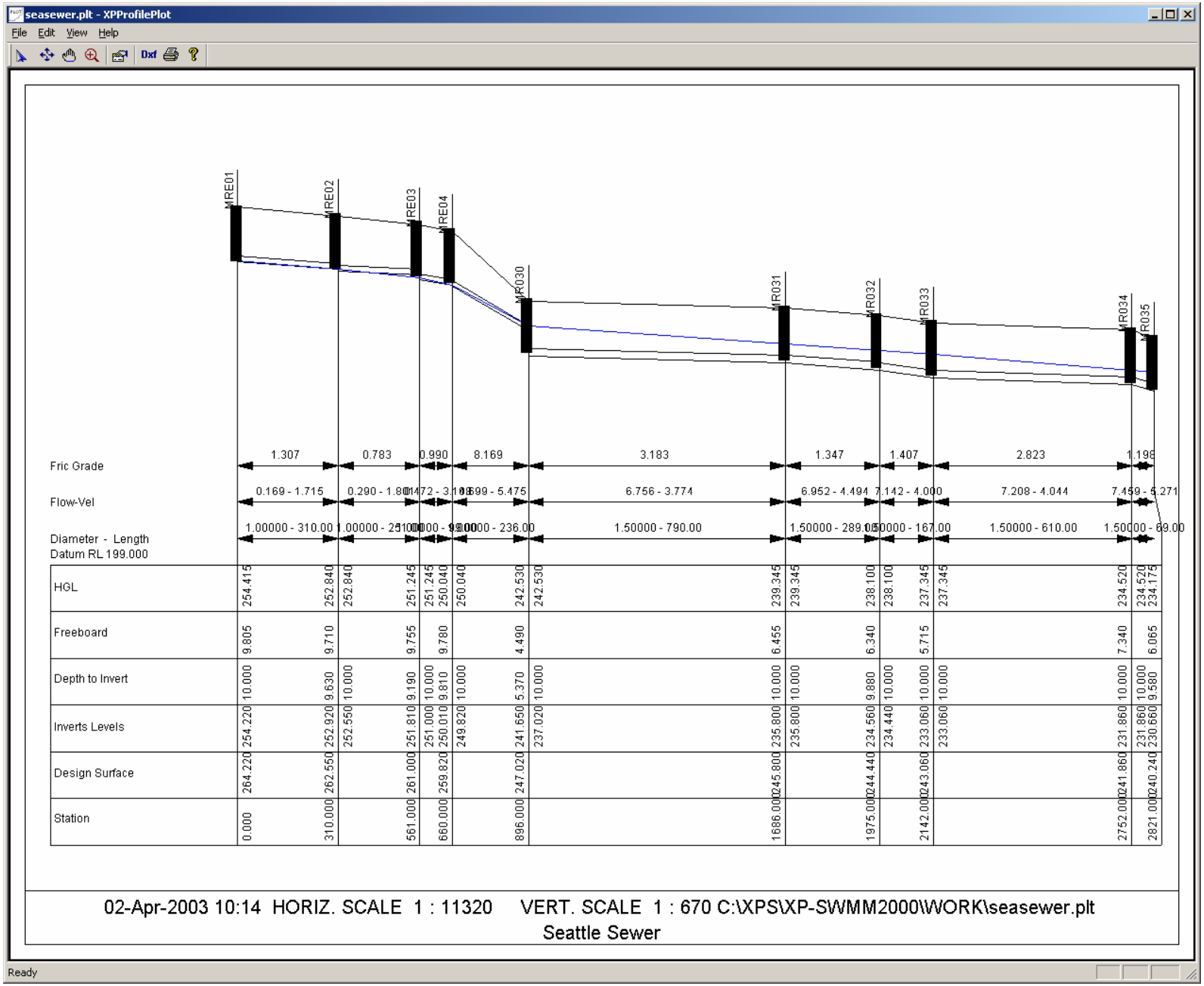
XP SOFTWARE

Show Gauged Data



XP SOFTWARE

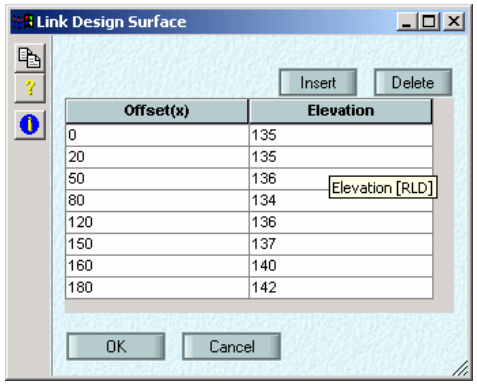
Profile Plotting Graphic

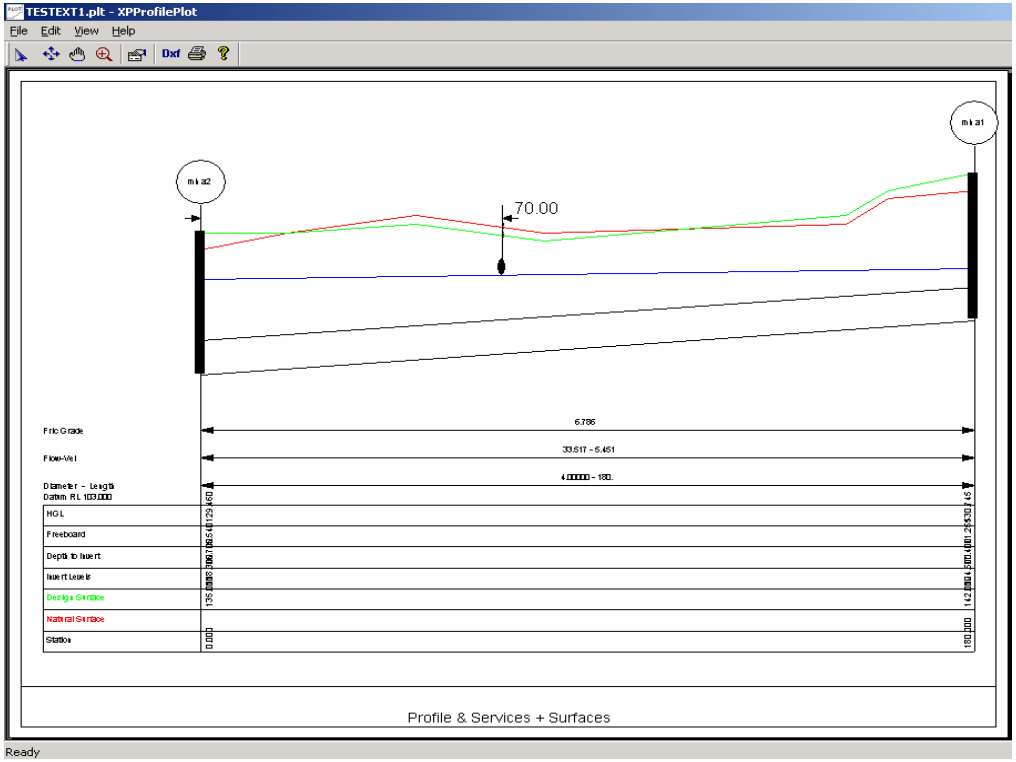


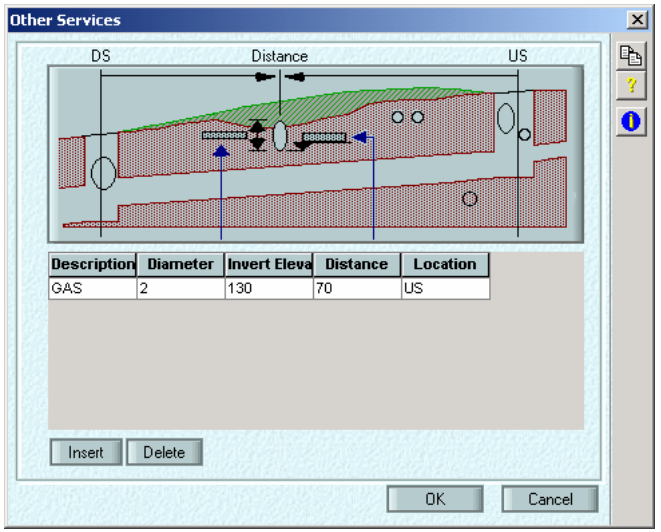
XP SOFTWARE

Profile Details

- Profile plots allow natural surface, design surface and services to be plotted

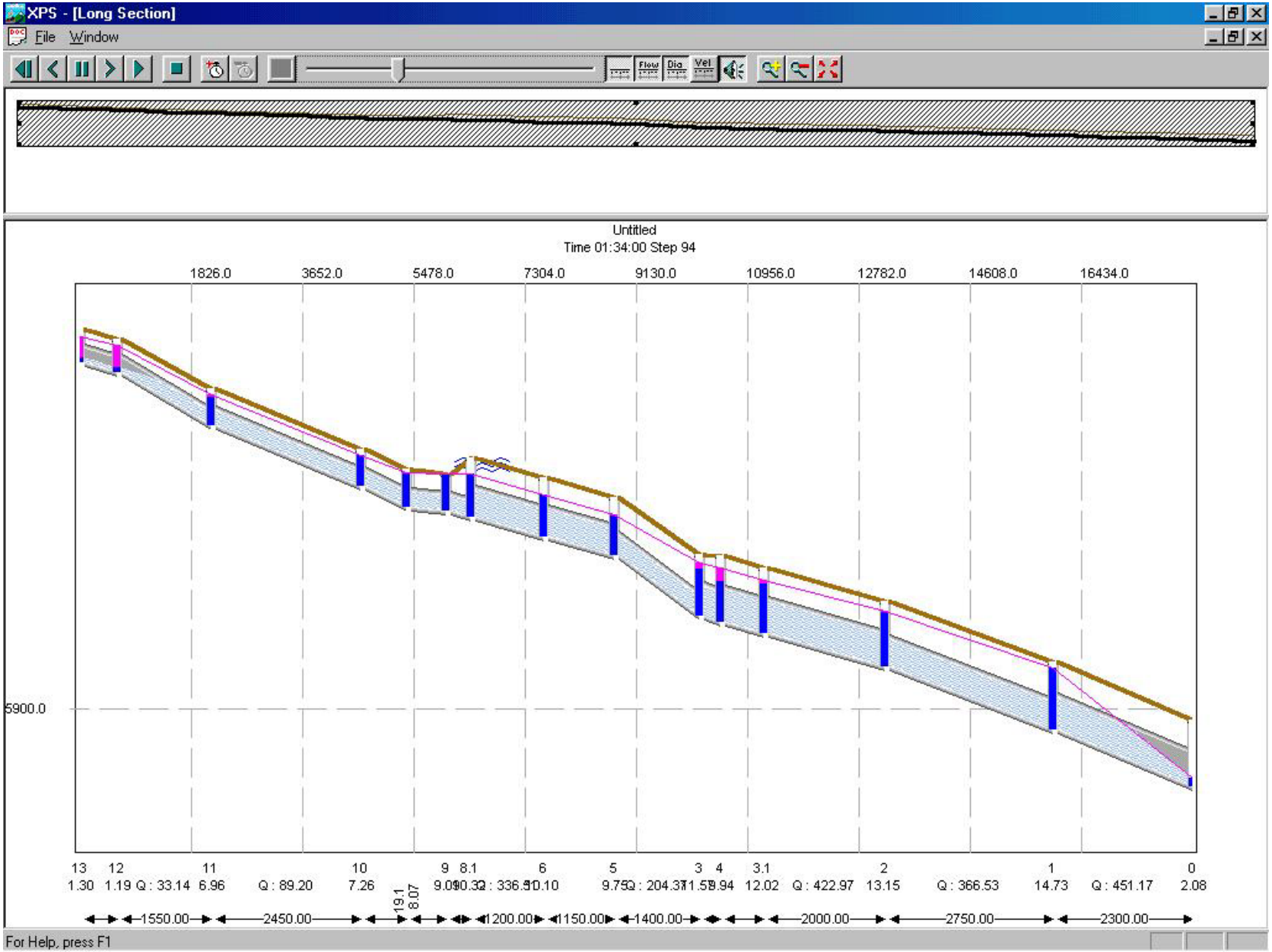






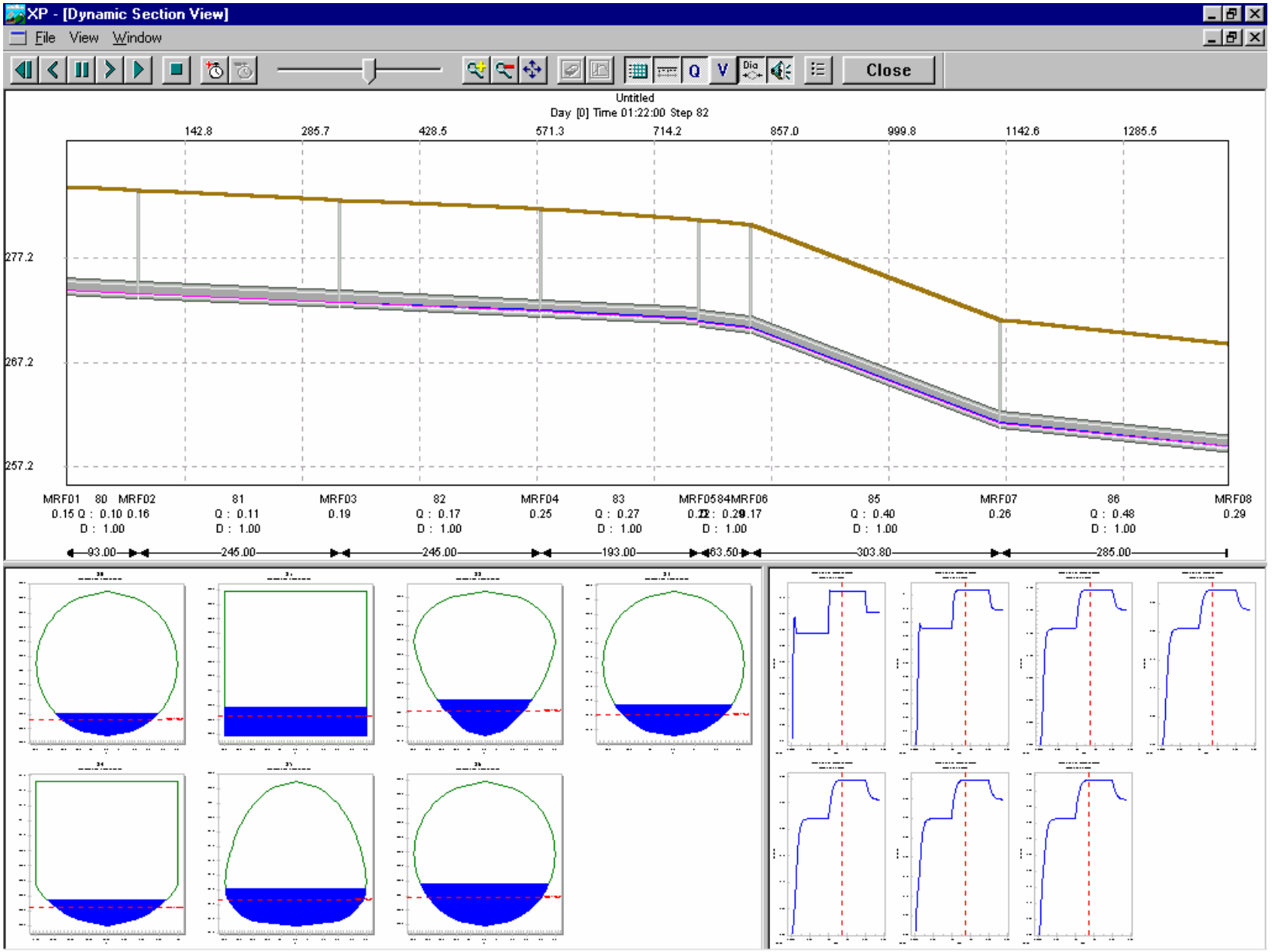
XP SOFTWARE

Dynamic Long-Section View



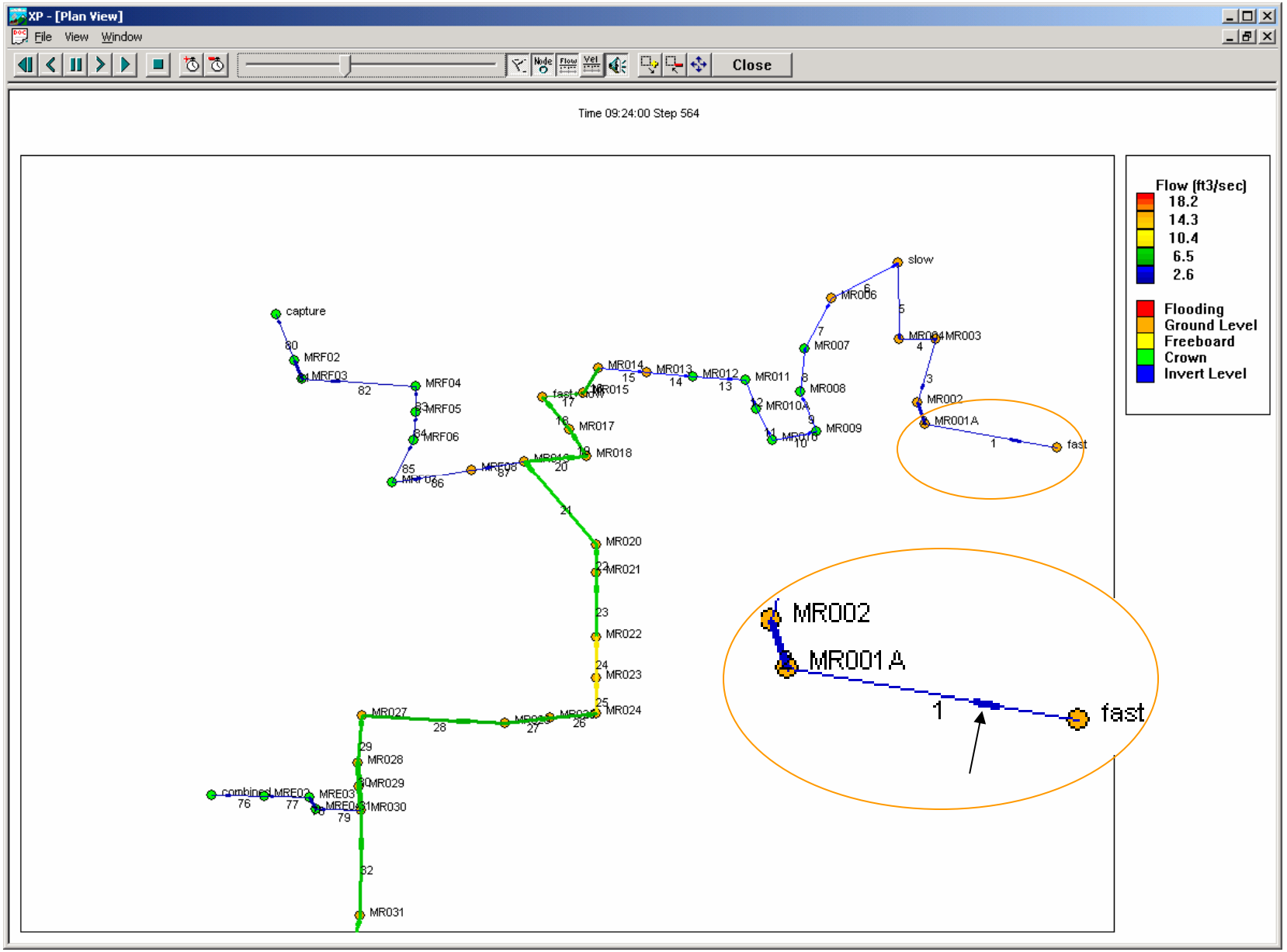
XP SOFTWARE

Dynamic Section Views

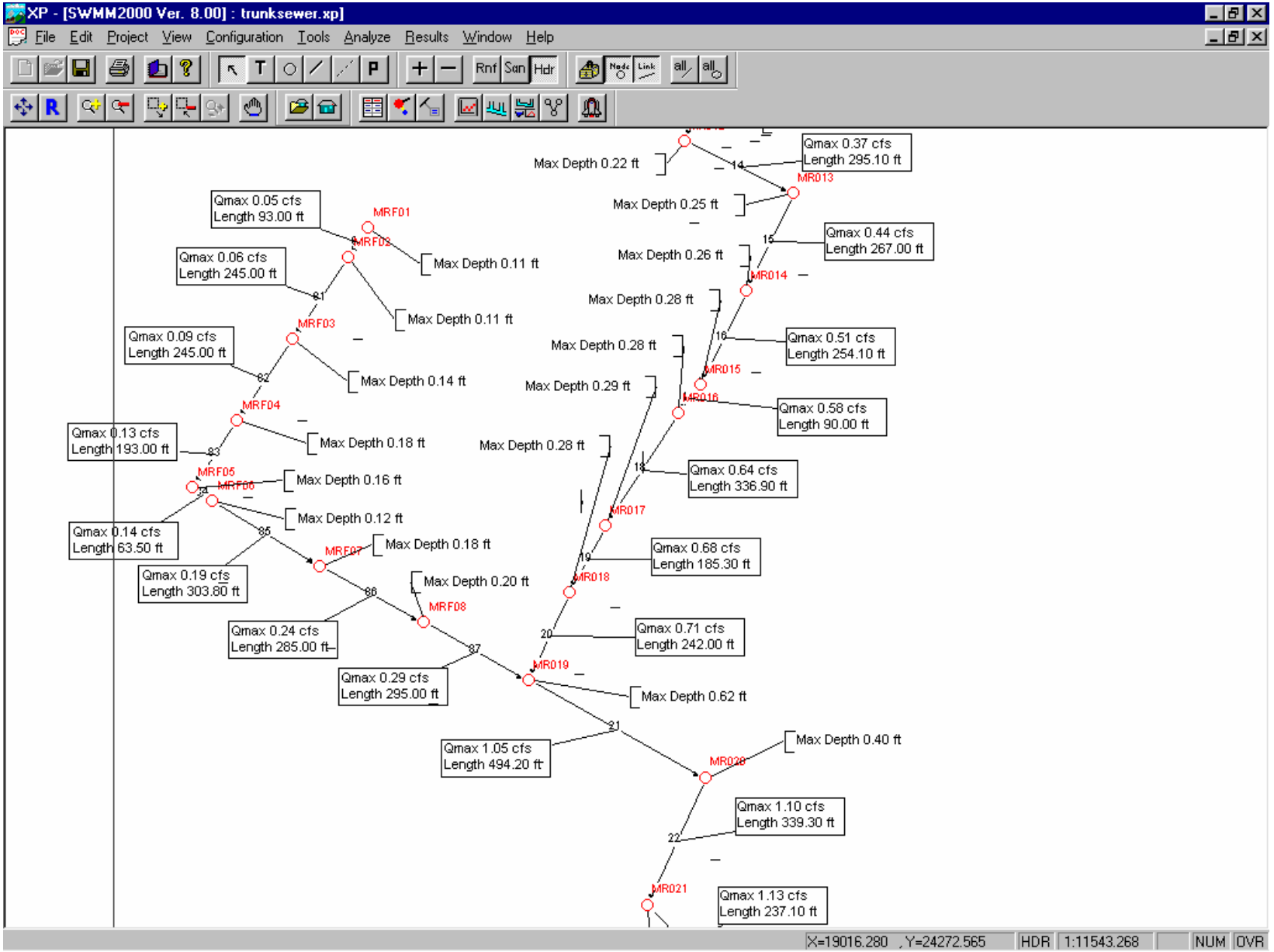


XP SOFTWARE

Dynamic Plan View

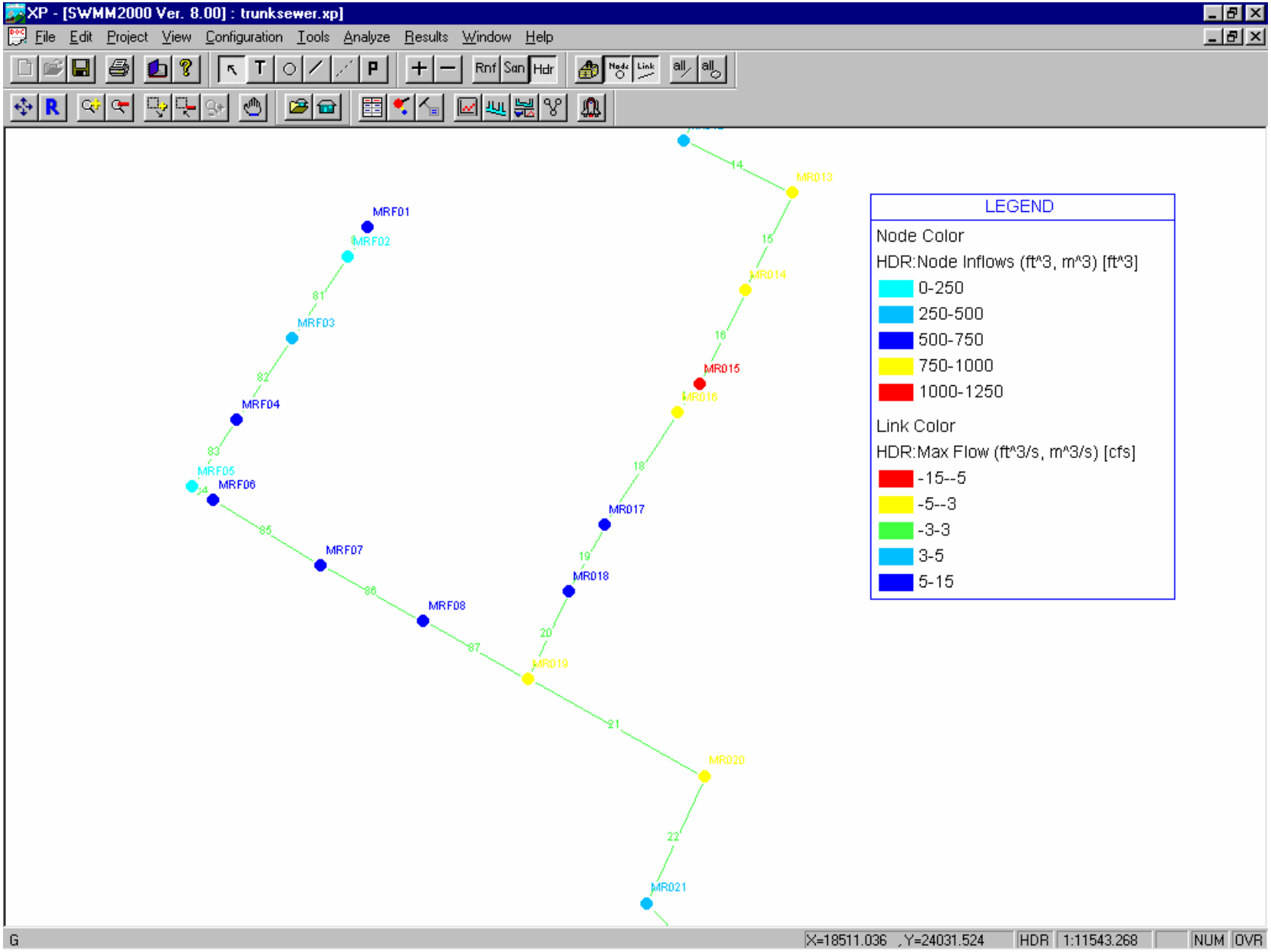


Spatial Reports



XP SOFTWARE

Graphical Encoding



XP SOFTWARE

Tabular Reports – Export to .CSV or .TXT

- Export report to text files .TXT or .CSV using icons or the Export menu
- Good link to GIS for model results

XPS

File Export Window Help

TEXT CSV

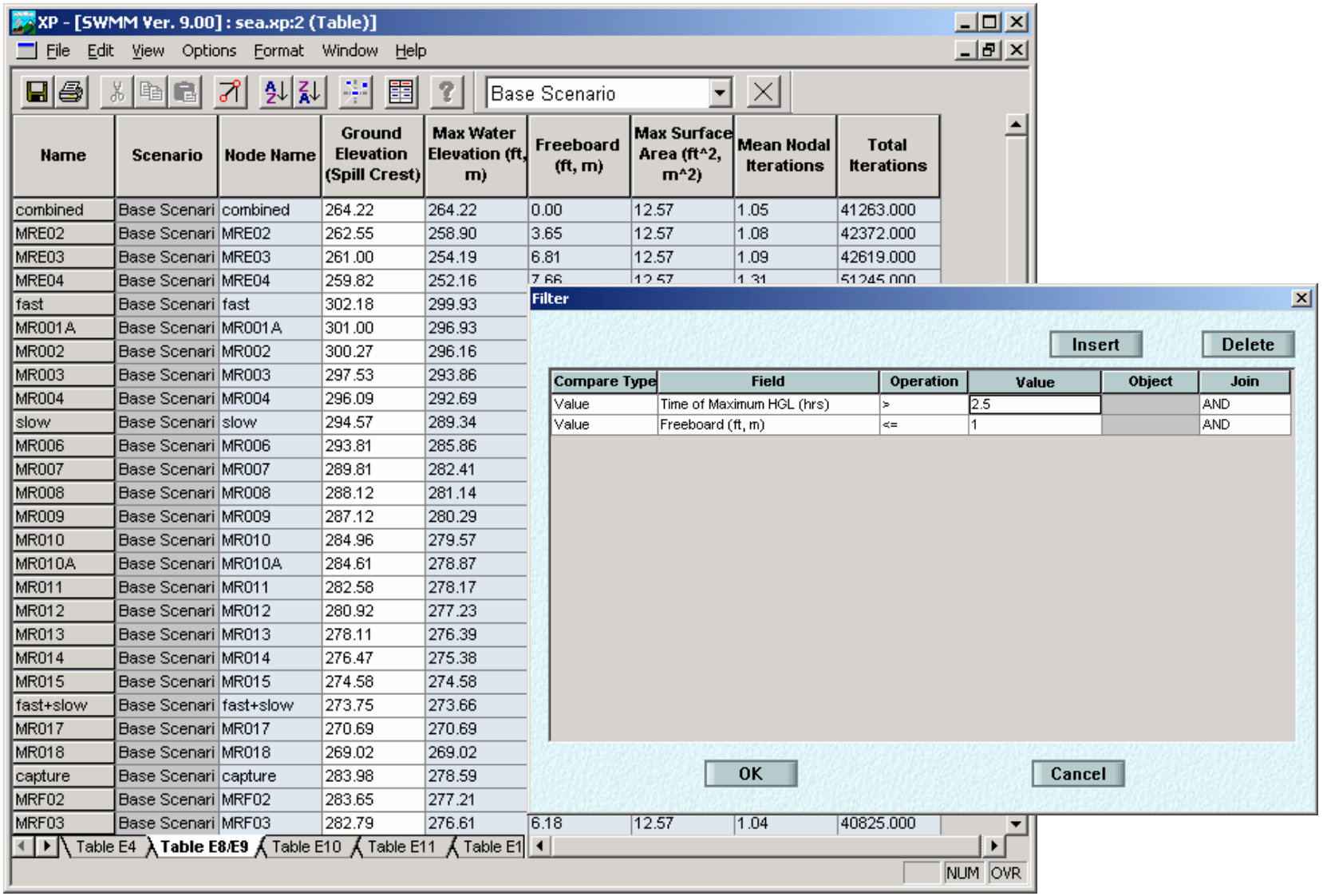
XP-SWMM2000 Hydraulics Table

Link Name			Link data							Link Results	
Link	USnode	DSnode	Conduit type	Dia	Width	Roughness	Slope %	US invert leve	DS invert level	Peak flow	Max Velocity
				m	m		%	m	m	cms	m/s
1	MR001	MR001A	Circular	1.000	-	0.013	-	292.180	291.130	0.006	0.393
2	MR001A	MR002	Circular	1.000	-	0.013	-	291.130	290.270	0.047	1.459
3	MR002	MR003	Circular	1.000	-	0.013	-	290.270	288.250	0.068	1.694
4	MR003	MR004	Circular	1.000	-	0.013	-	288.250	286.880	0.139	2.999
5	MR004	MR005	Circular	1.000	-	0.013	-	286.880	284.930	0.140	2.345
6	MR005	MR006	Circular	1.000	-	0.013	-	284.930	283.880	0.198	2.677
7	MR006	MR007	Circular	1.000	-	0.013	-	283.880	281.740	0.199	2.695
8	MR007	MR008	Circular	1.250	-	0.013	-	281.740	278.300	0.254	3.369
9	MR008	MR009	Circular	1.250	-	0.013	-	278.120	277.260	0.273	2.587
10	MR009	MR010	Circular	1.250	-	0.013	-	277.120	275.690	0.280	2.668
11	MR010	MR010A	Circular	1.250	-	0.013	-	274.960	274.720	0.285	2.643
12	MR010A	MR011	Circular	1.250	-	0.013	-	274.610	272.580	0.335	2.415
13	MR011	MR012	Circular	1.250	-	0.013	-	272.580	271.570	0.341	2.440
14	MR012	MR013	Circular	1.250	-	0.013	-	270.920	268.830	0.372	2.529
15	MR013	MR014	Circular	1.250	-	0.013	-	268.110	266.470	0.438	2.491

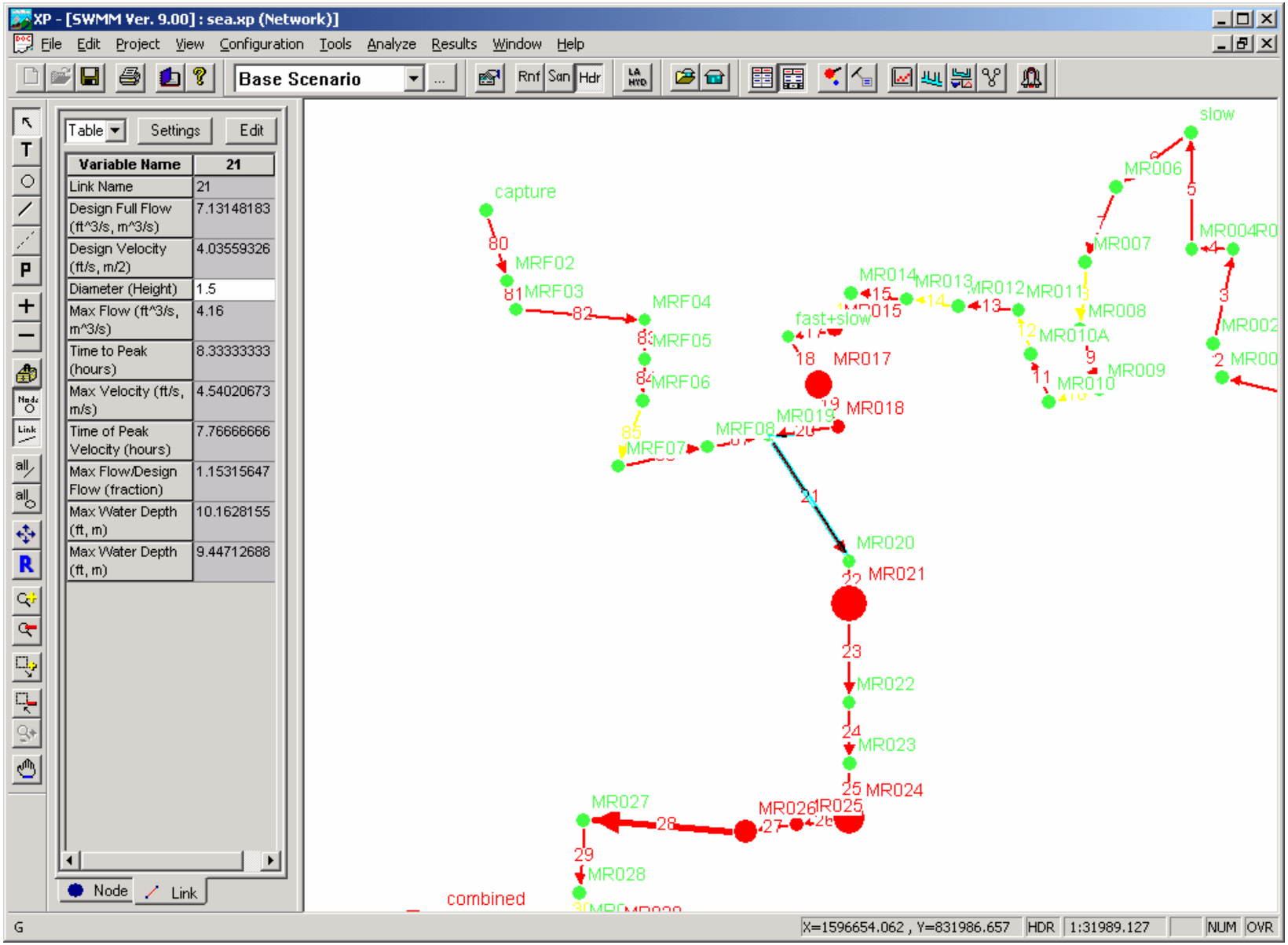
XP SOFTWARE

XP Tables

- Exchange data with other programs and XP-Tables
- Create a Query by using filters

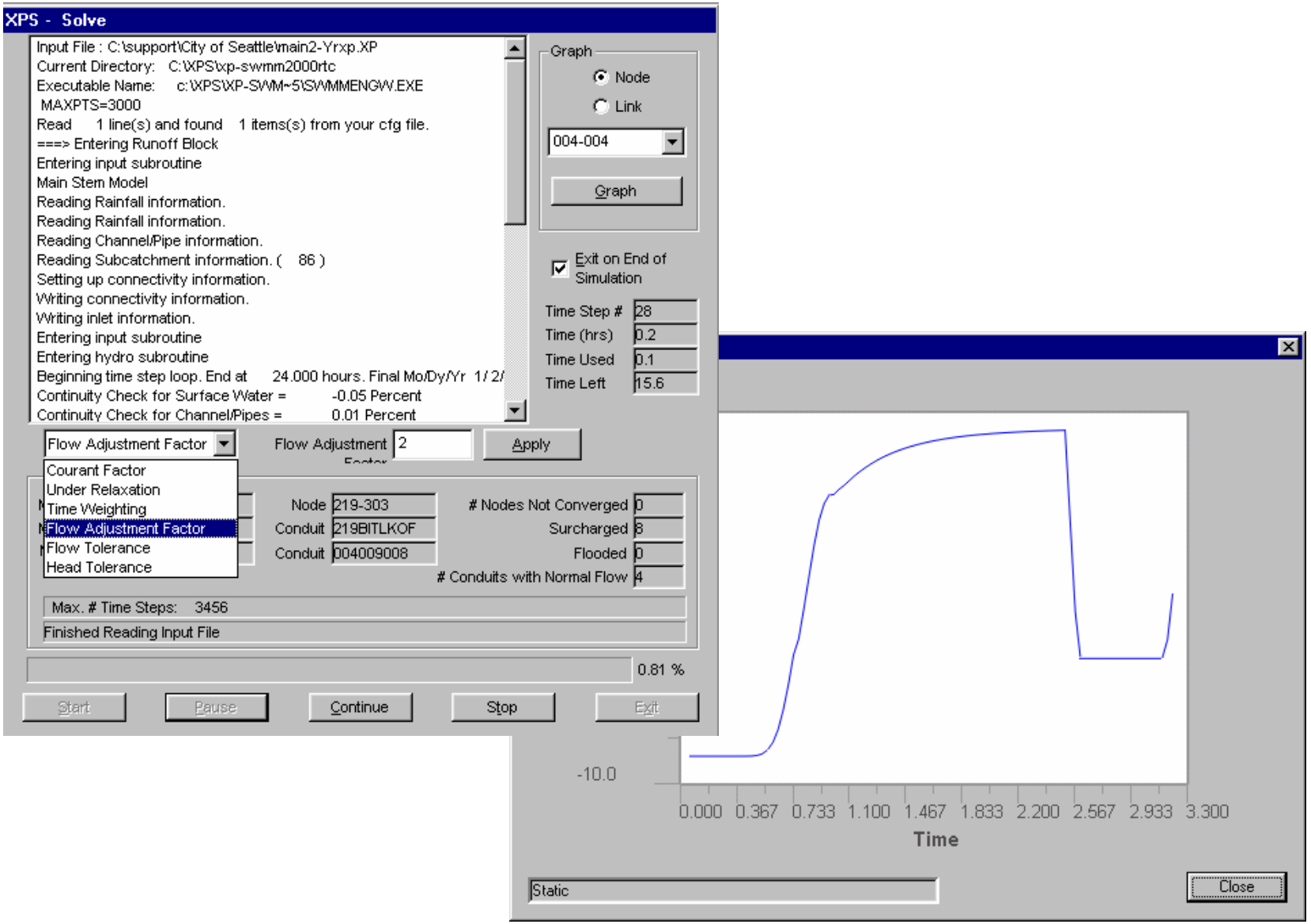


Quick Data View



XP SOFTWARE

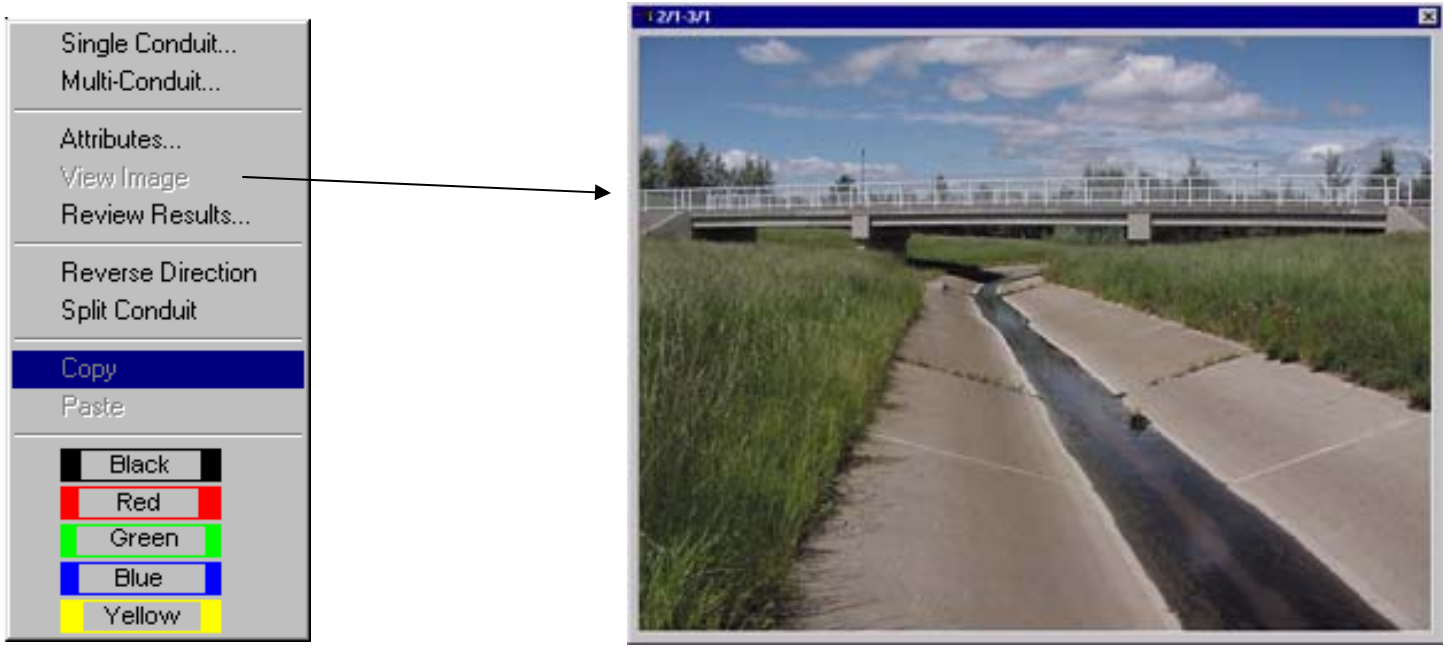
Interactive Analysis Engine and Runtime Graphing



XP SOFTWARE

Attach Images to Links and Nodes

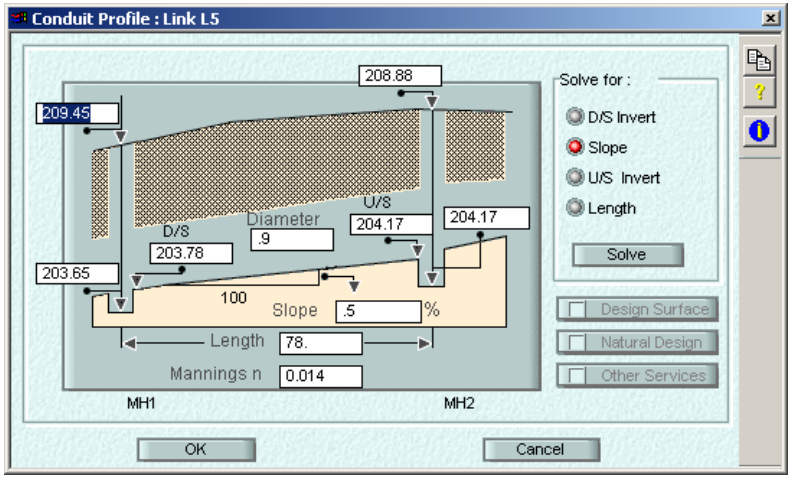
- XP-SWMM supports images attached to both NODES and LINKS in the network. This feature is extremely useful when working on large projects with a range of photographs available.
- Most of the standard windows image file types are supported, ranging from BMP, JPG through to TIFF.



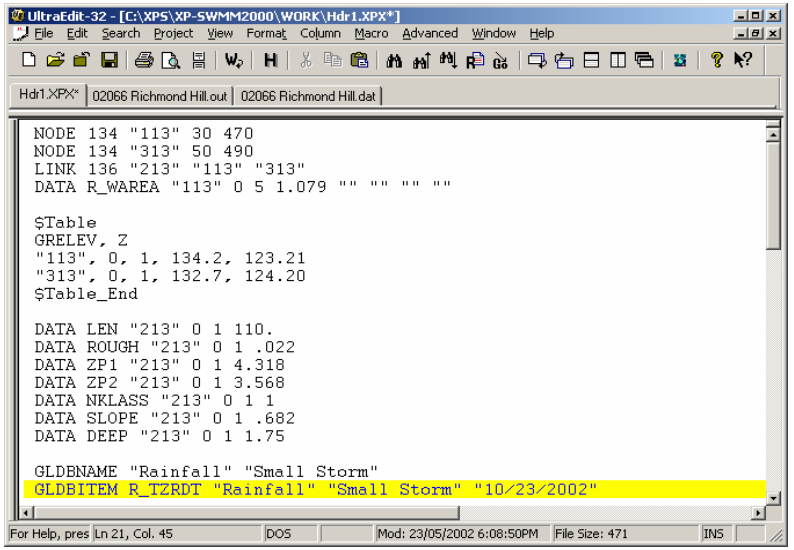
XP SOFTWARE

Interface: Efficient Model Input Tools

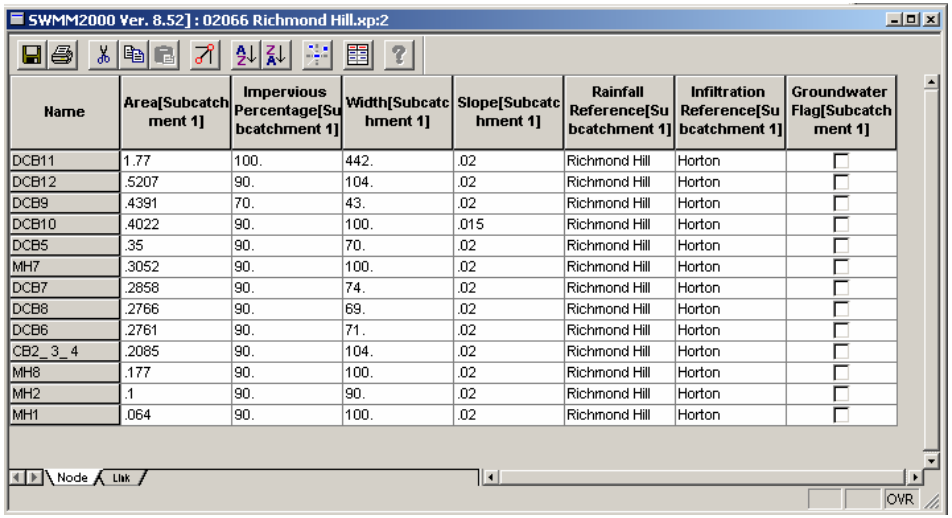
Data Entry in Dialogs

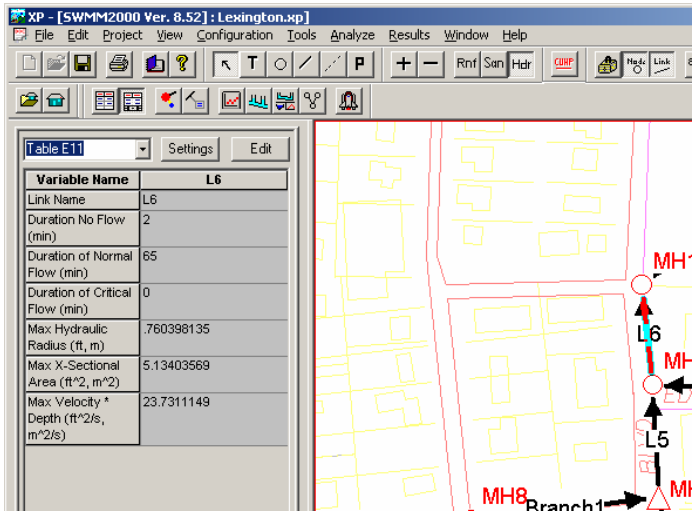


Text File (XPX, CSV) Import



XP Tables & Quick View Data Forms – Tabular Input & Copy/Paste

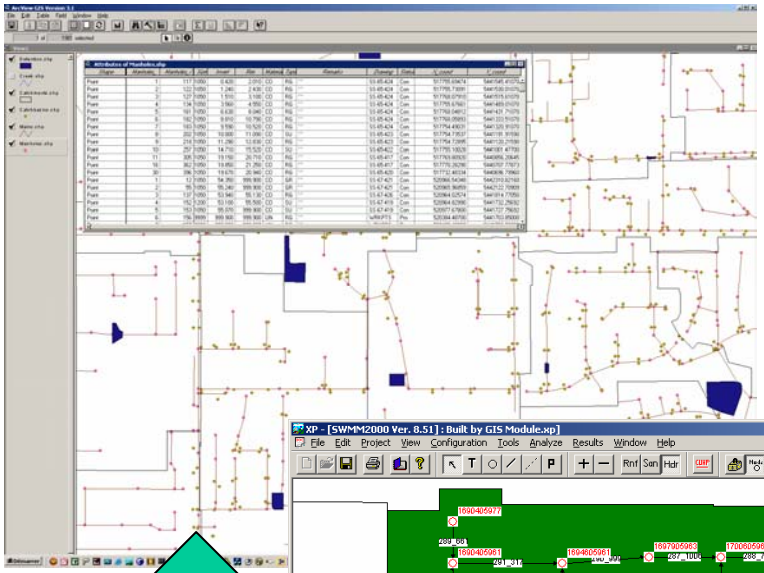


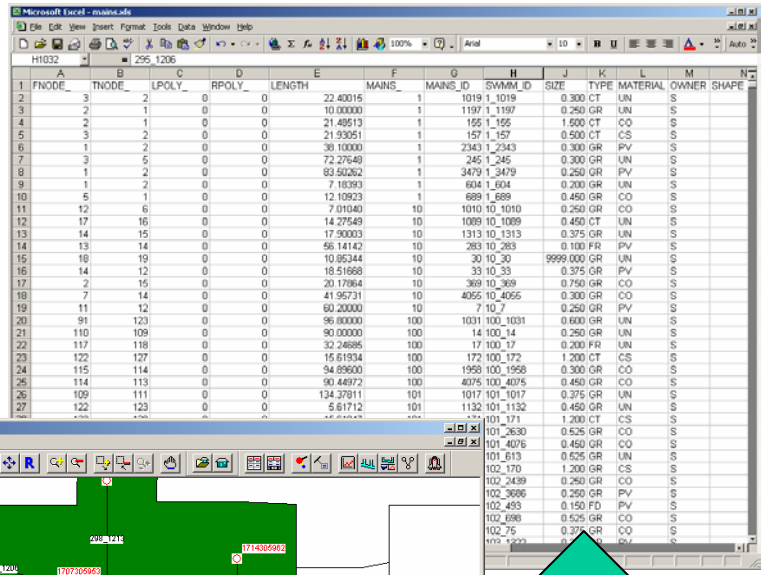


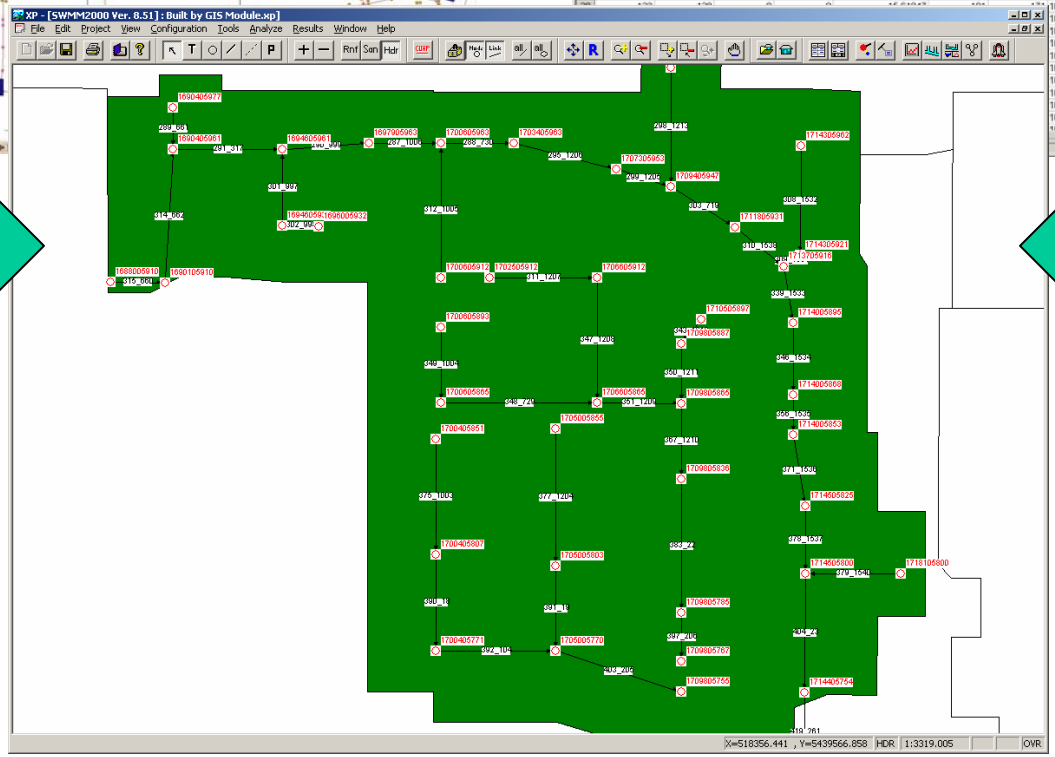
XP SOFTWARE

Dynamic with Link to External Data: XP-GIS

GIS Module

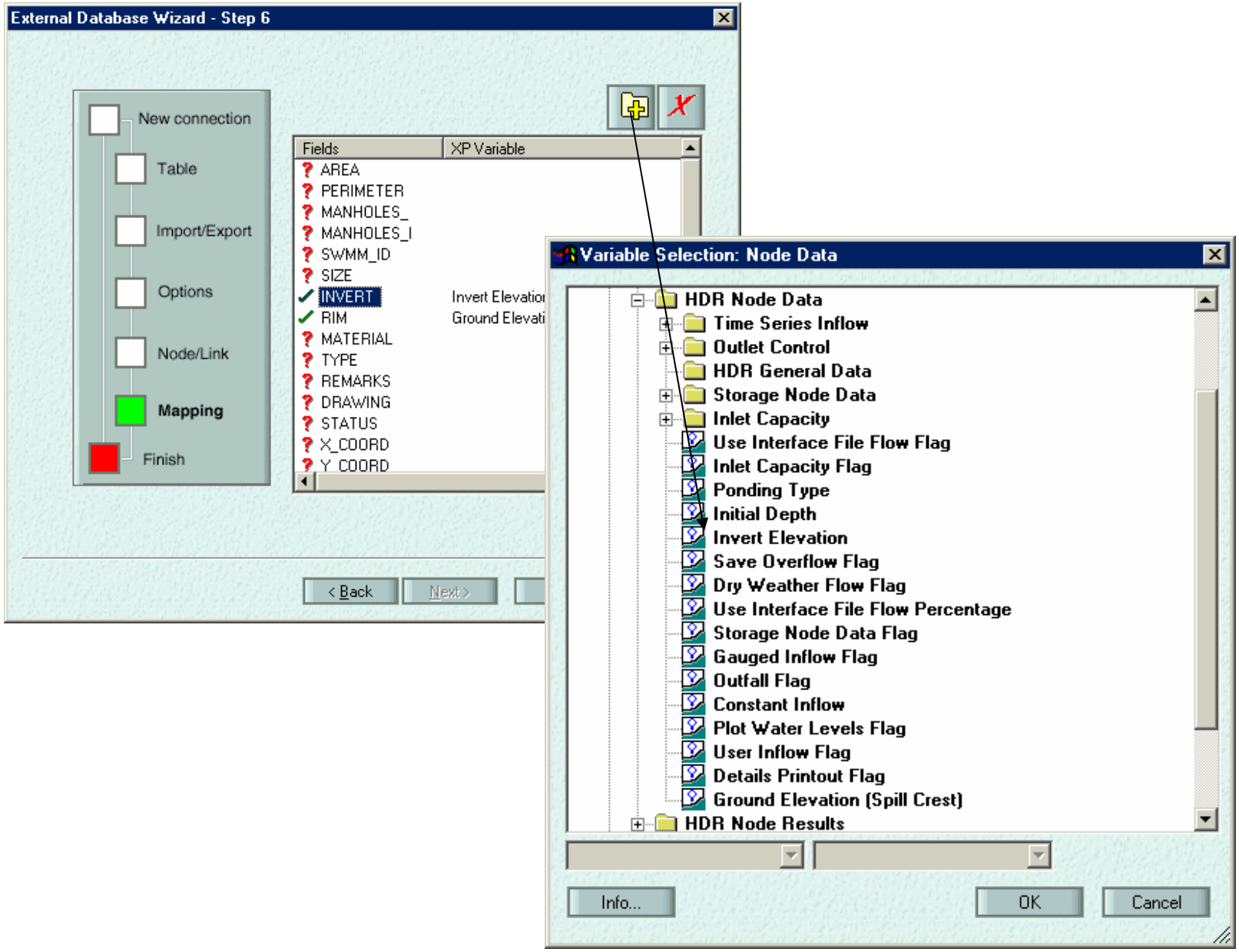






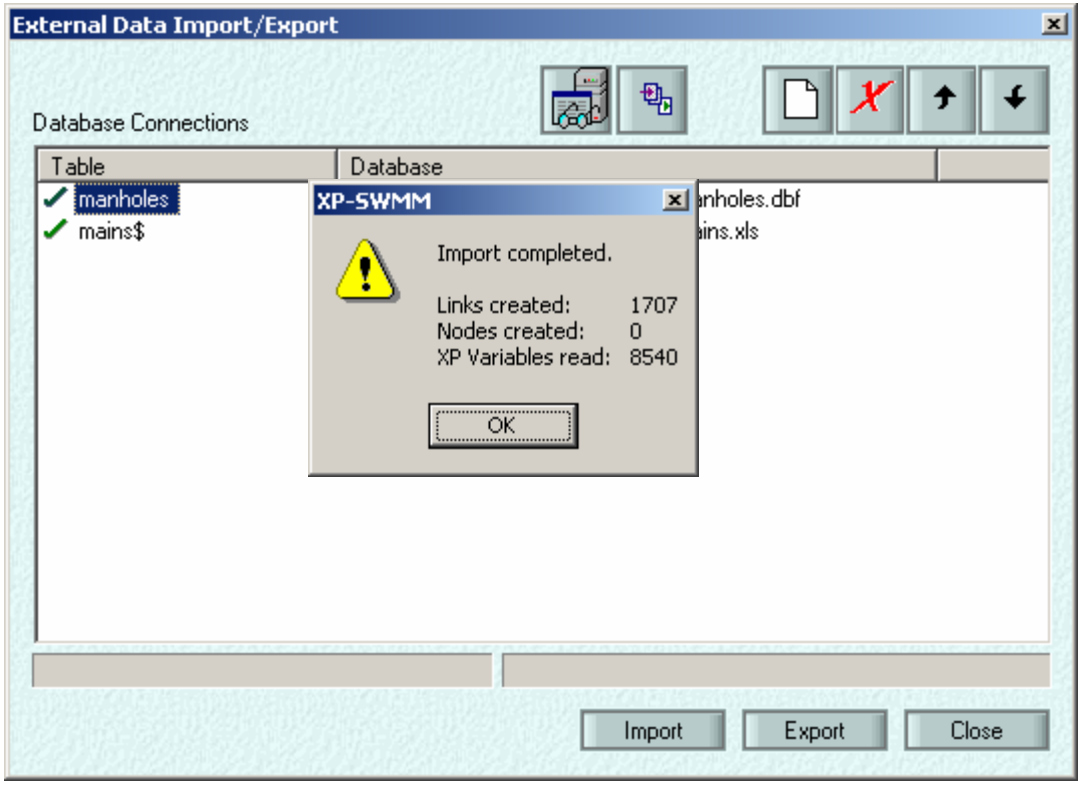
XP SOFTWARE

Map your data to the XP database definitions



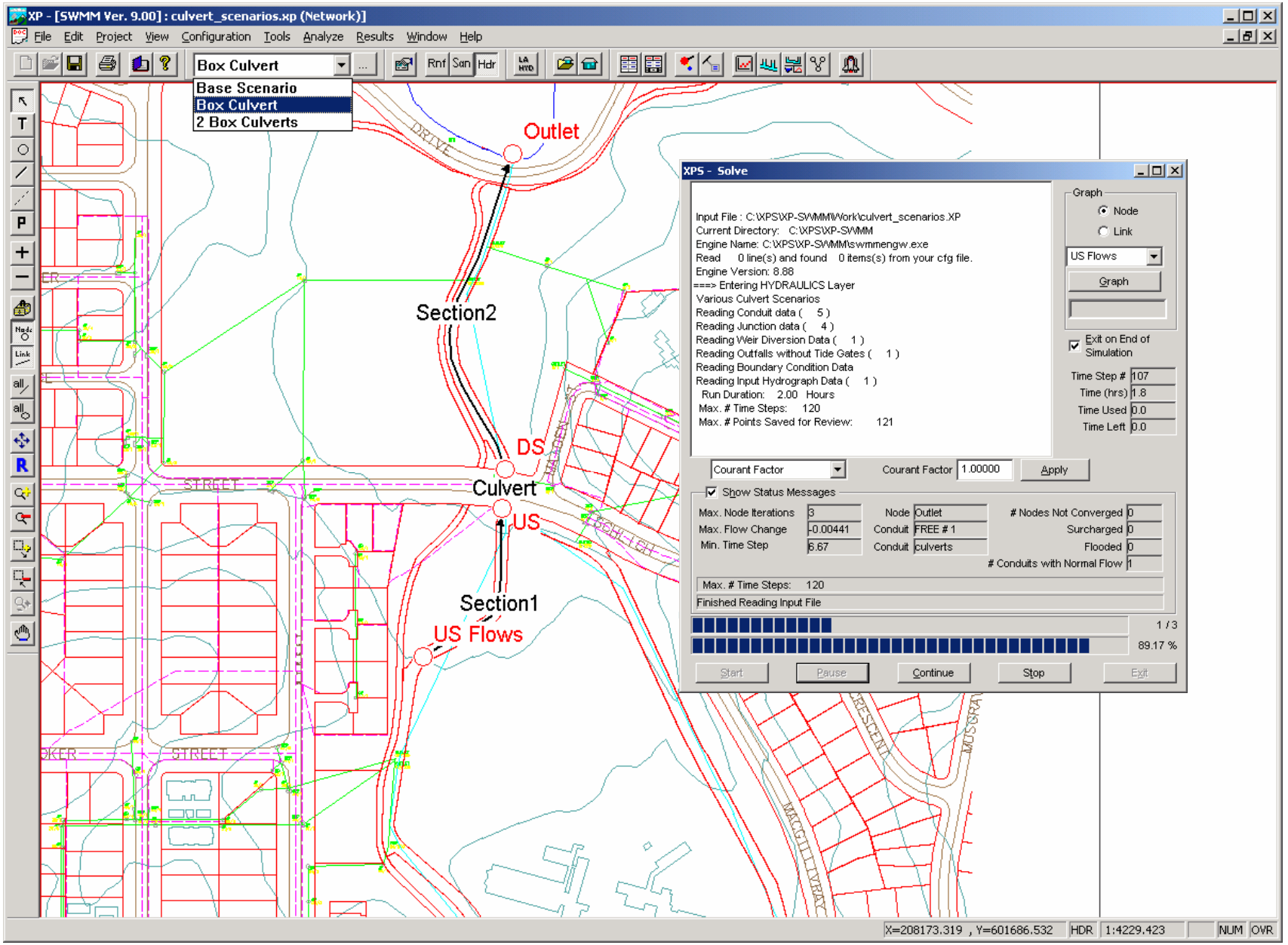
XP SOFTWARE

Once configured a simple click allows data to be imported, exported and updated



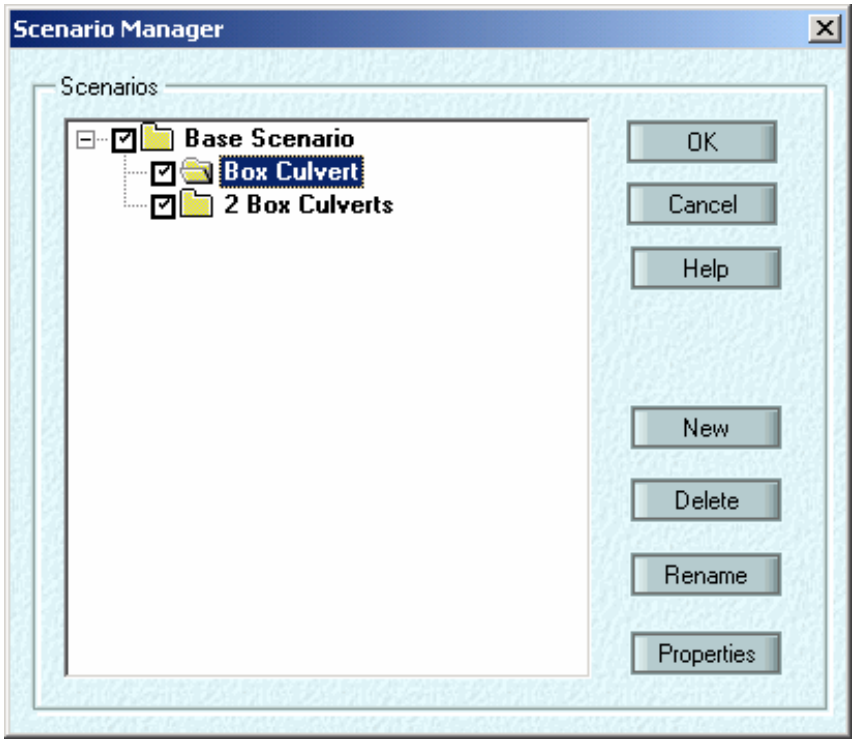
XP SOFTWARE

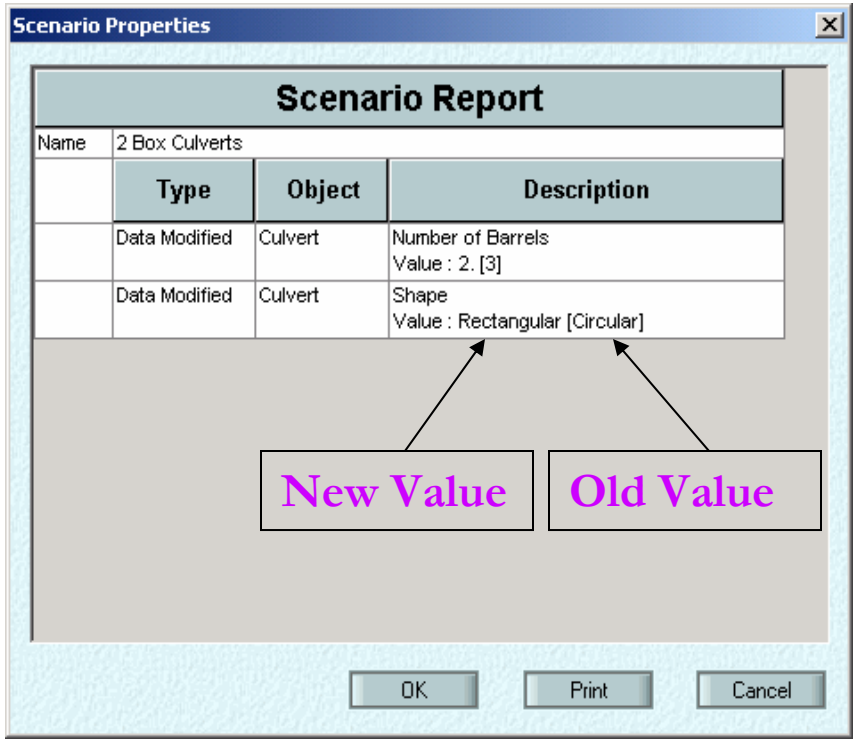
Scenario Manager-Multiple Runs



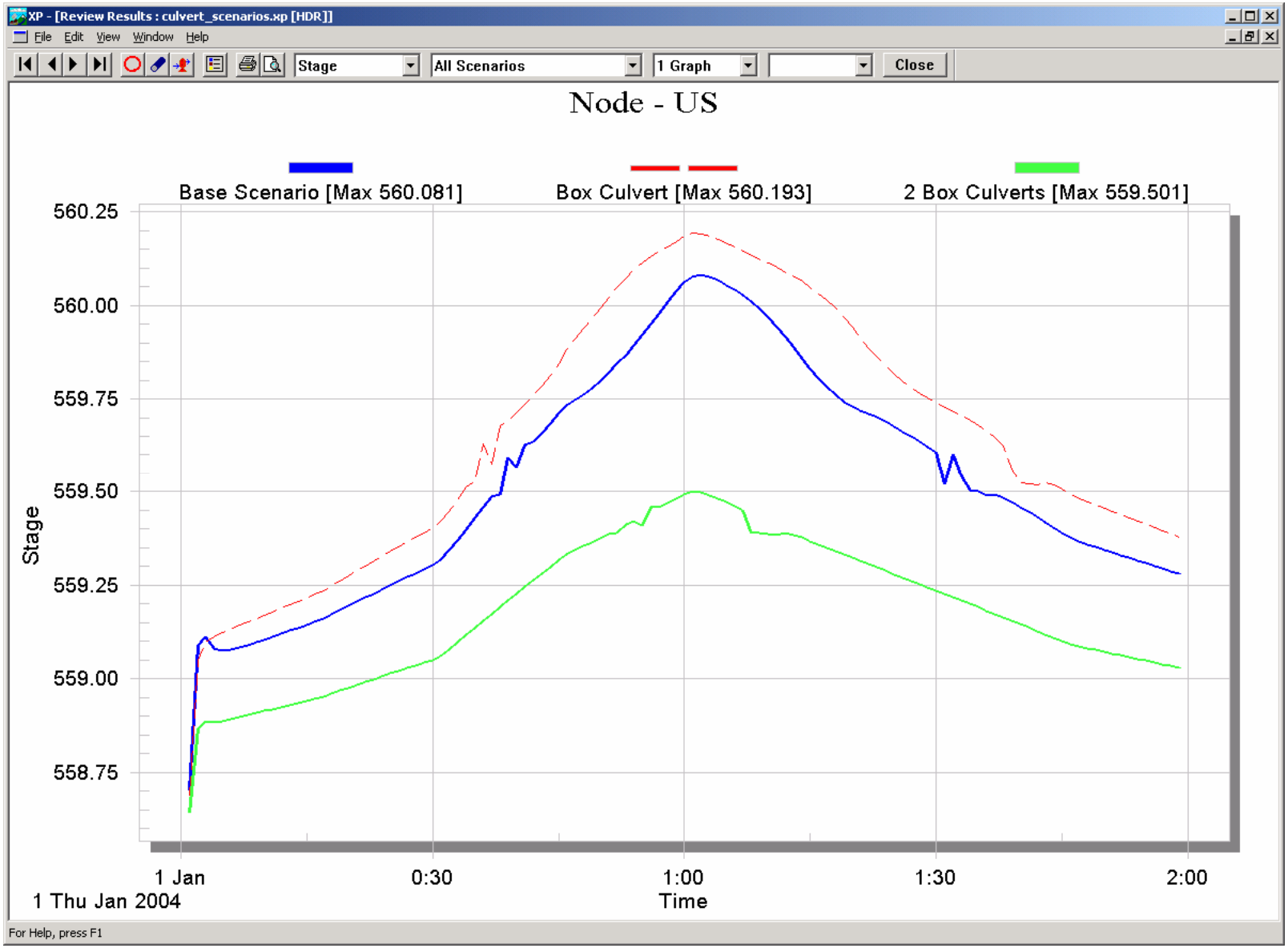
Scenario Manager-Management and Reports

- Add, Delete and Activate Scenarios in the Manager Dialog
- Scenario Properties Track Changes Automatically





Scenario Manager- Series of Review Results



XP SOFTWARE

Scenario Manager – Multiple Results in Tables

XP - [SWMM Ver. 9.00] : culvert_scenarios.xp:2 (Table)]

File Edit View Options Format Window Help

ALL Scenarios

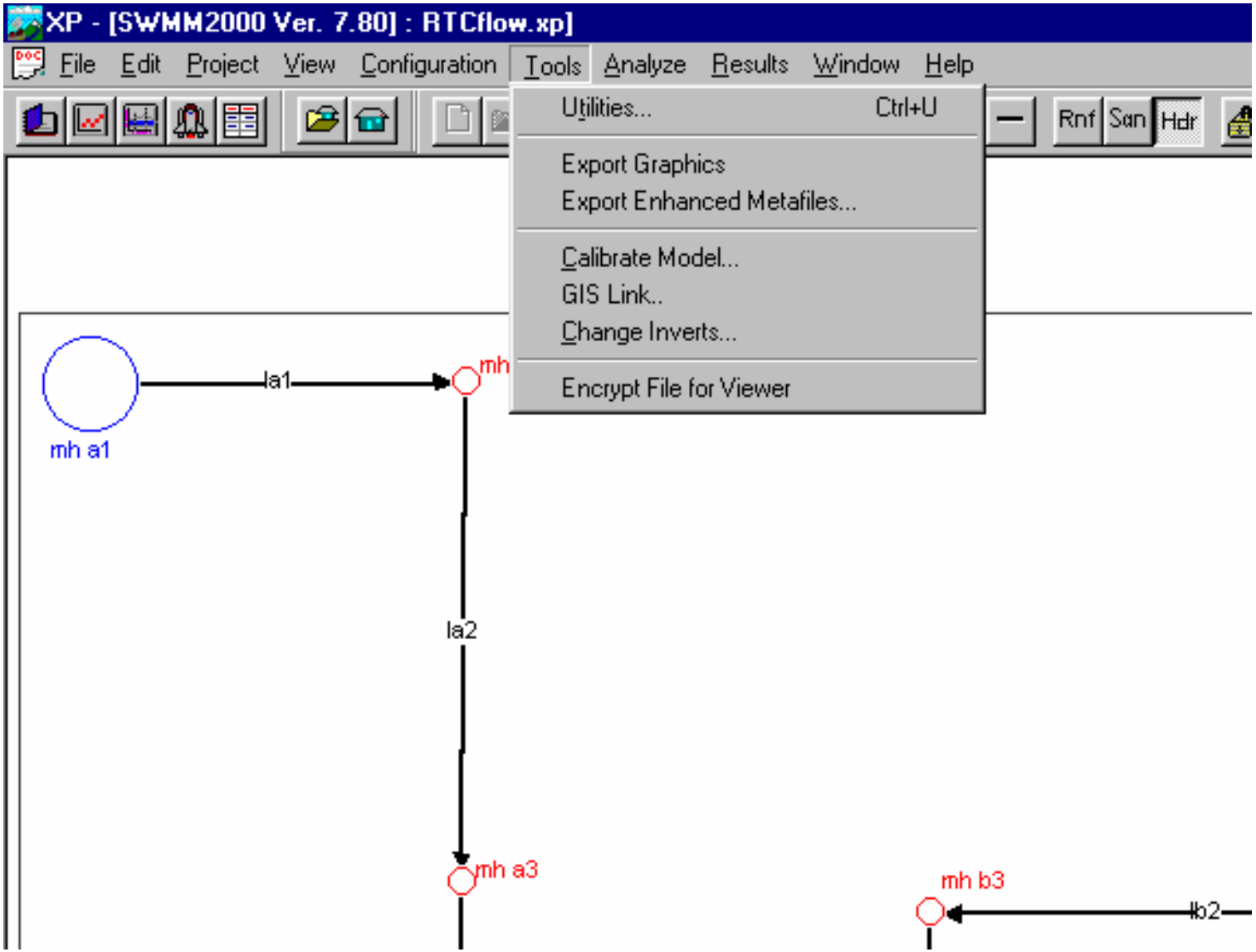
Name	Scenario	Shape	Diameter (Height)	Number of Barrels	Length	Max Flow (ft^3/s, m^3/s)	Weir Name	Weir Crest Elevation	Max Water Elevation (ft, m)
Section1	Base Scenari	Natural	0.75	1.0	150.00	5.96			562.03
	Box Culvert					5.97			562.05
	2 Box Culvert					5.96			561.96
culverts	Base Scenari	Rectangul	1.00	2.00	31.00	5.75			560.08
	Box Culvert					5.37			560.19
	2 Box Culvert					5.95			559.50
Overtop	Base Scenari						Overtop	560.00	560.08
	Box Culvert								560.19
	2 Box Culvert								559.50
Section2	Base Scenari	Natural	1.50	1.0	270.00	5.91			559.19
	Box Culvert					5.94			559.19
	2 Box Culvert					5.94			559.19

Culvert Detail

NUM OVR

XP SOFTWARE

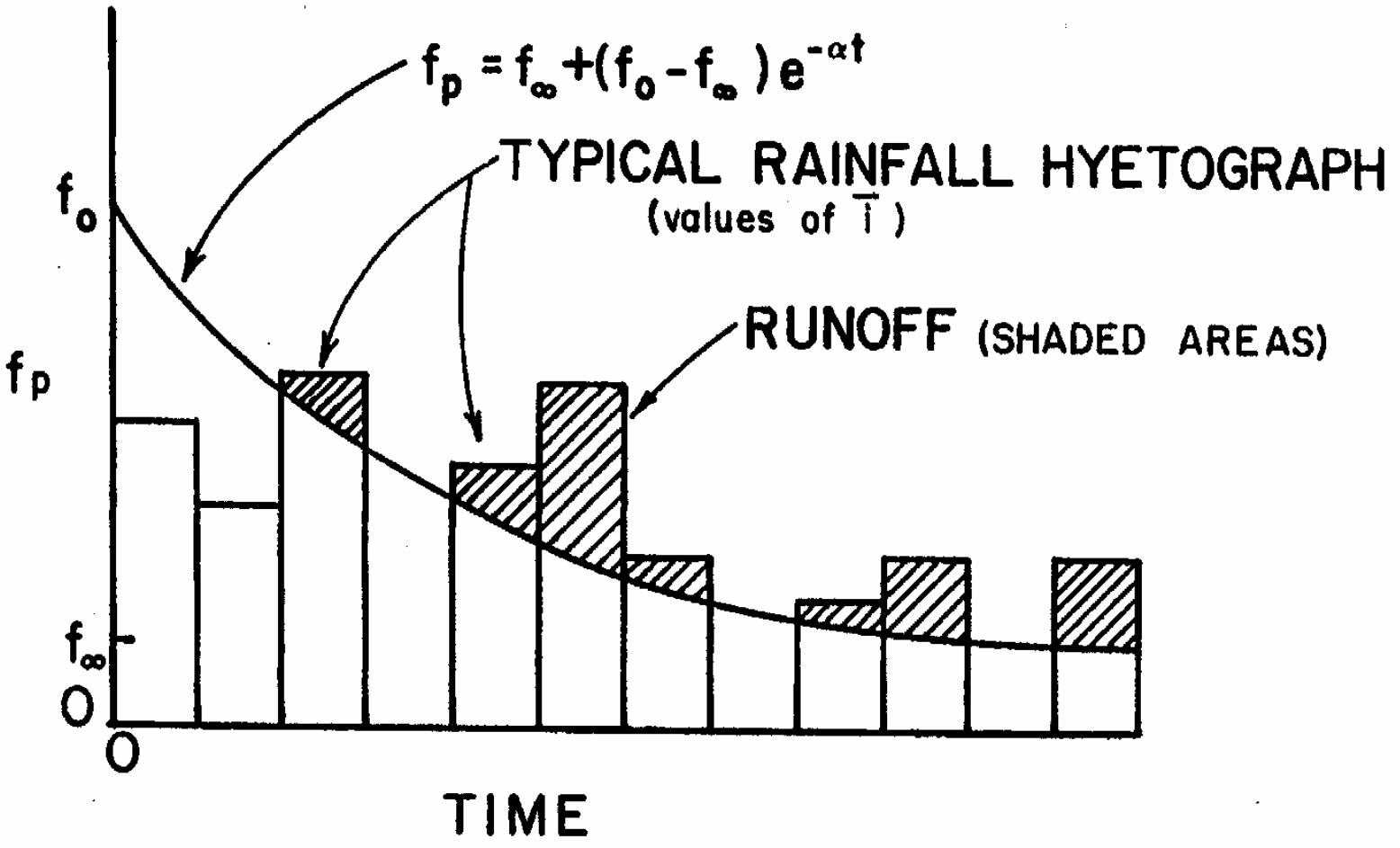
Encryption for XP-Viewer



XP SOFTWARE

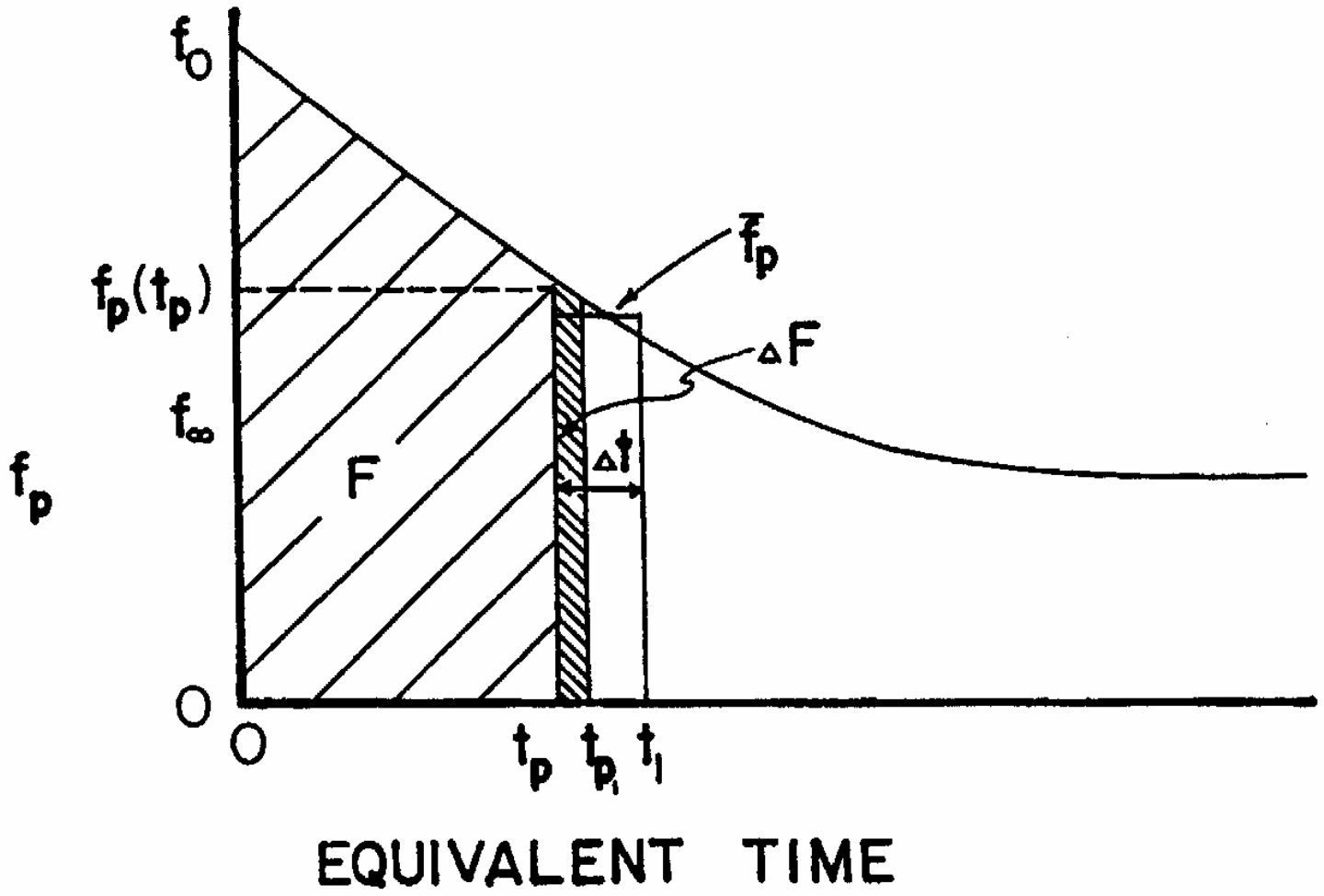
Slides for Specific Questions

Horton Infiltration Curve



XP SOFTWARE

Horton Equivalent Time



XP SOFTWARE

Green-Ampt Equation

For $F < Fs$: $f=i$ and $F_s=S_u\,IMD/(i/K_s-1)$ for $i>K_s$
and no calculation of F_s for $i<K_s$

For $F > Fs$: $f = f_p$ and $f_p=K_s(1+S_u\,IMD/F)$

Where:

f = infiltration rate, ft/sec,

f_p = infiltration capacity, ft/sec,

i = rainfall intensity, ft/sec,

F = cumulative infiltration volume, this event, ft,

F_s = cumulative infiltration volume to cause surface saturation, ft,

S_u = average capillary suction at the wetting front (SUCT), ft water,

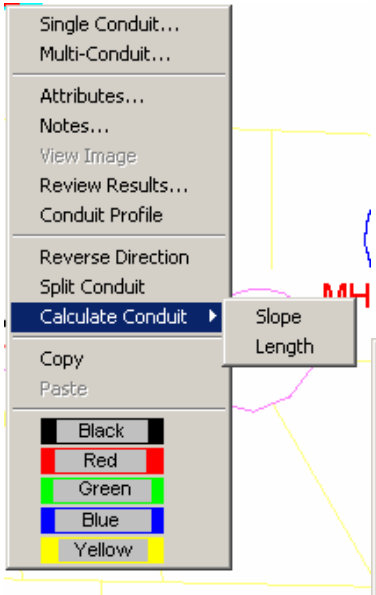
IMD = initial moisture deficit for this event (SMDMAX), ft/ft, and

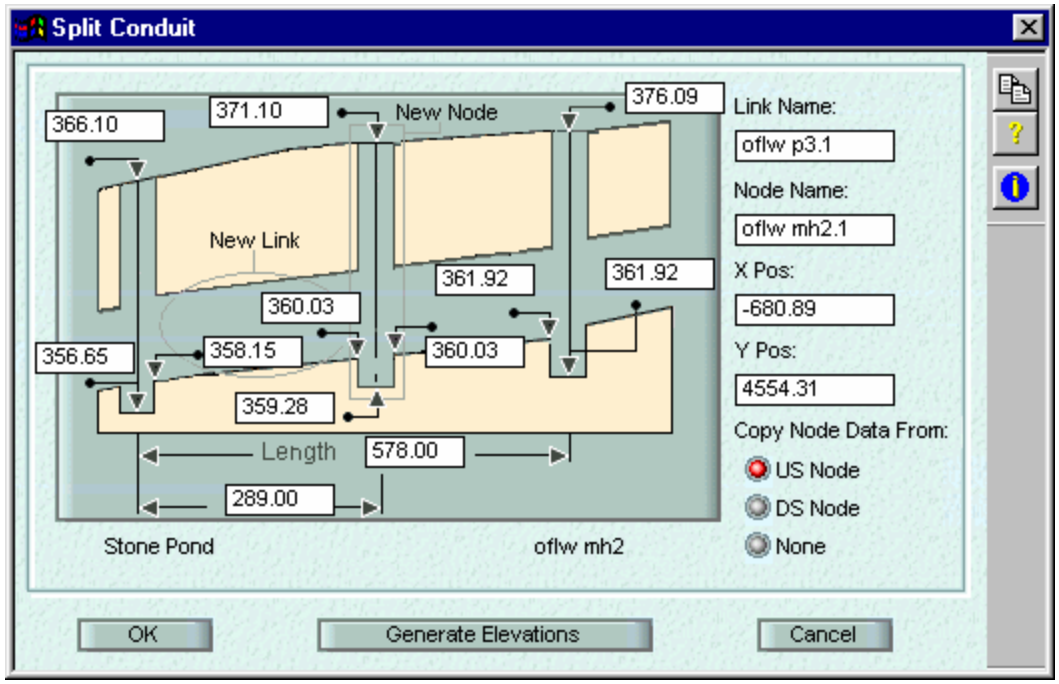
K_s = saturated hydraulic conductivity of soil, (HYDCON) ft/sec.

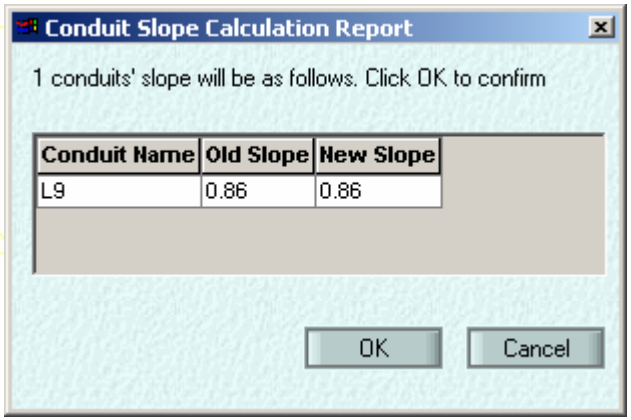
XP SOFTWARE

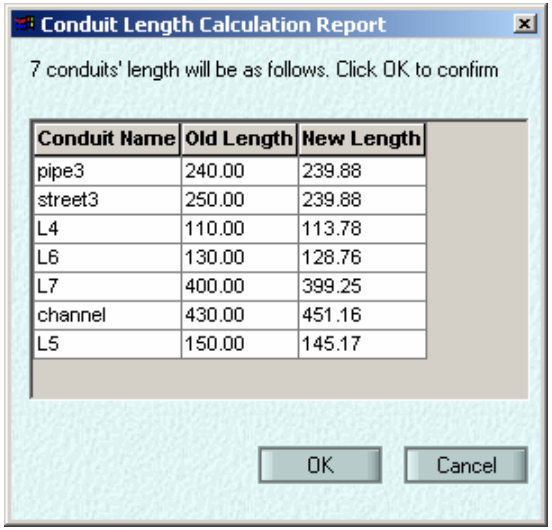
Powerful Network Editing

Split Links
Reverse Direction
Calculate Slope
Calculate Length









XP SOFTWARE